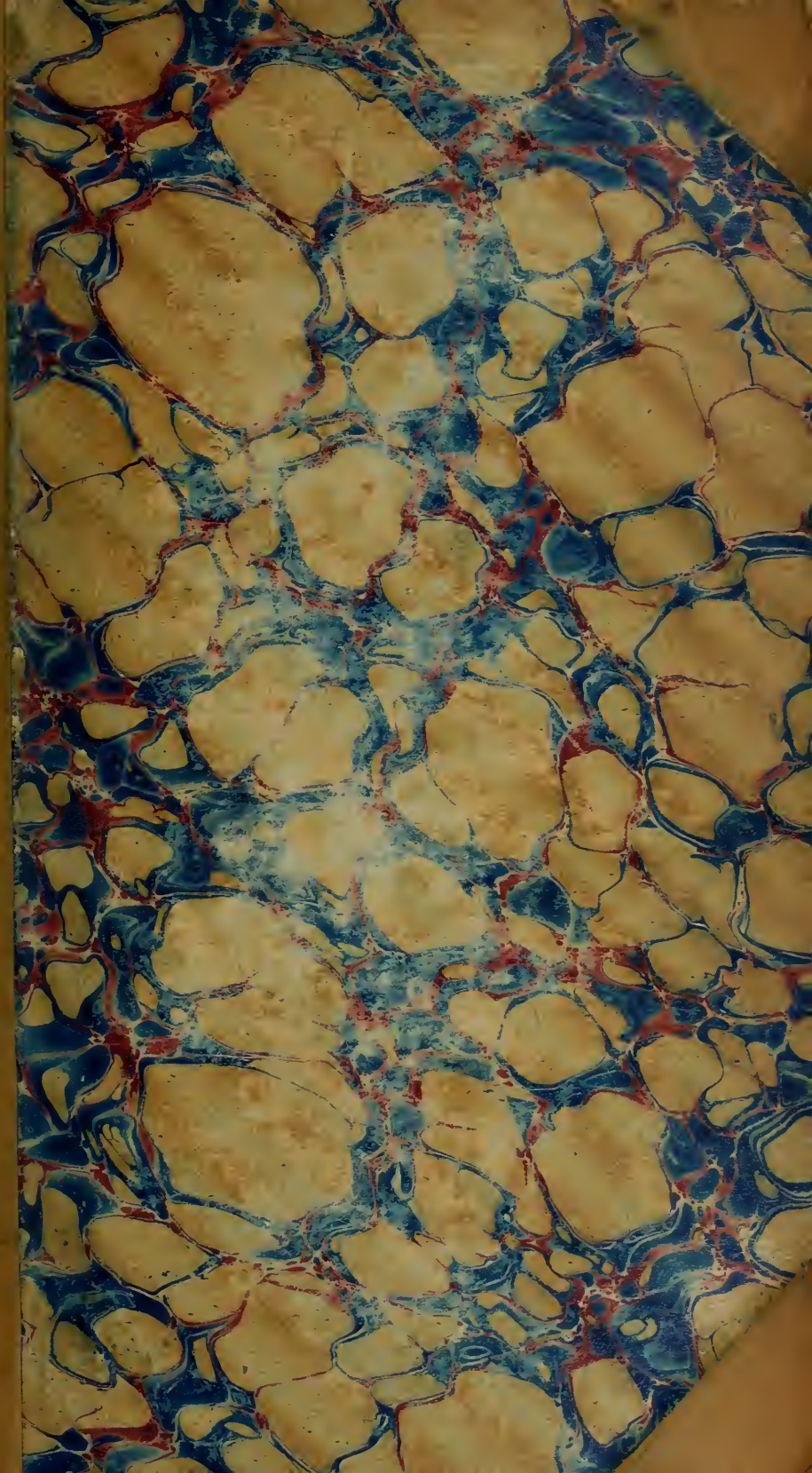

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THE JOURNAL

—OF THE—

FRANKLIN INSTITUTE,

DEVOTED TO

SCIENCE AND THE MECHANIC ARTS.

EDITED BY

Prof. Persifor Frazer, D.Sc., Prof. Edwin J. Houston, Theo. D. Rand,
Prof. Coleman Sellers, Prof. H. W. Spangler, Committee on Publications,
with the Assistance of
Dr. Wm. H. Wahl, Secretary of the Institute.

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Vol. CXXXII.

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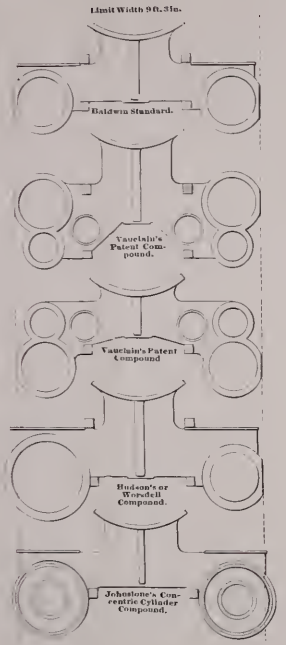
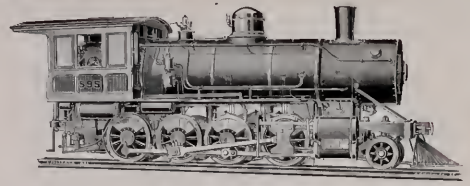
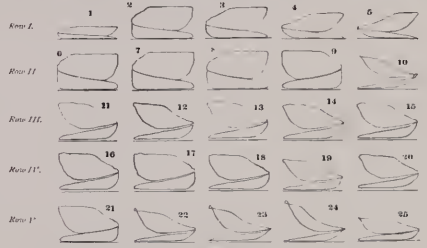




Indicator Diagrams taken upon Lehigh Valley and Pennsylvania Railroad, May 13 to 21, 1891.



Row I.—Philadelphia and Reading R. R., Preliminary Trial, May 10, 1891.

No. 1 speed not noted.
Nos. 2 and 3 . . . . . 60 revolutions per minute or 9·11 miles per hour.
No. 4. . . . . 84 " " 12·74 " "
" 5. . . . . 72 " " 10·92 " "

Row II.—Lehigh Valley R. R., Mountain Grade, May 14, 1891.

No. 6, ... 54 revolutions per minute or 8·19 miles per hour.
" 7. . . . . 60 " " 9·11 " "
" 8, ... 66 " " 10·01 " "
" 9, ... 90 " " 13·65 " "
" 10, ... 150 " " 22·75 " "

Row III.—Pennsylvania R. R., Philadelphia to Harrisburg, May 17, 1891.

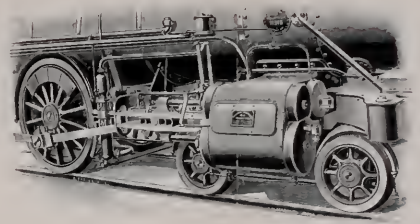
No. 11 . . . . . 126 revolutions per minute or 19·11 miles per hour
" 12, ... 132 " " 20·02 " "
" 13, ... 156 " " 23·66 " "
" 14, ... 162 " " 24·57 " "
" 15, ... 162 " " 24·57 " "

Row IV.—Pennsylvania R. R., Harrisburg to Altoona, May 18, 1891.

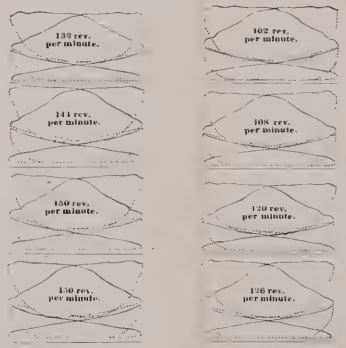
No. 16, ... 102 revolutions per minute or 15·47 miles per hour
" 17, ... 108 " " 16·38 " "
" 18, ... 132 " " 20·02 " "
" 19, ... 138 " " 20·95 " "
" 20, ... 180 " " 27·30 " "

Row V.—Pennsylvania R. R., Altoona to Harrisburg, May 20, 1891, taken by Test Department of P. R. R.

Nos. 21 and 22 speed not noted
No. 23, ... 250 revolutions per minute or 37·85 miles per hour.
Nos. 24 and 25 speed not noted.

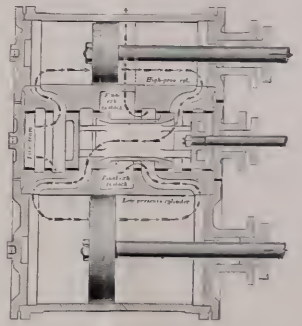


Indicator Diagrams Taken on Philadelphia & Reading Railroad, May 28, 1891.



VAUCLAIN'S COMPOUND LOCOMOTIVE ENGINE.

Diagram Showing Compound Cylinder and Piston Slide Valve.



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VOL. CXXXII. JULY, 1891. No. 1

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VAUCLAIN'S COMPOUND LOCOMOTIVE.

[*Abstract of the Report of the Committee on Science and the Arts.*]

[No. 1,555.] HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, September 3, 1890.

The sub-committee of the Committee on Science and the Arts, constituted by the Franklin Institute of the State of Pennsylvania, to whom was referred, for examination and report,

SAMUEL M. VAUCLAIN'S COMPOUND LOCOMOTIVE STEAM ENGINE,

respectfully report that they have examined the same and find as follows:

The invention is the subject of United States Letters-Patent granted to Samuel M. Vauclain, respectively numbered and dated as follows: Nos. 406,011 and 406,012, both dated June 25, 1889, and No. 431,860, dated July 8, 1890.

The invention is illustrated in the drawings of said patents, and has been thoroughly tested in two engines built by the Baldwin Locomotive Works of this city, one of which your committee have examined in use upon the Baltimore and Ohio and Schuylkill River East Side Railways.

The engine, in general construction of boiler, furnace, frames, valve-gear, driving and truck-wheels, is the same as the Baldwin Standard passenger engines.

The difference between the Vauclain engine and the Standard engine is entirely in the cylinders, pistons, crossheads and valves.

The general appearance of the engine is shown in the frontispiece, *Fig. 1*, which represents the engine made for the New South Wales Government Railway, from which diagrams and results of tests here published were taken as hereinafter stated. The proportion and relation of the cylinders in size and position to each other and their attachment to the crosshead and the forms of the crosshead are depicted in *Fig. 2*, and susceptible of variation, as shown in *Figs. 3* and *4*, for differing requirements of service.

The valve is of the type known as piston valves, consisting of a hollow plug with cylindric rims at proper intervals fitting in a hollow cylinder with apertures registering with the rim of the plugs leading to and from the ends of the cylinders, from the steam pipe and to the exhaust pipe.

In *Fig. 5* is shown a lengthwise central section of the valve, valve seat and cylinders, with arrows indicating the direction of the flow of steam which shows the manner in which steam enters the high-pressure cylinder and propels the piston in it, and on the return stroke passes through a central chamber in the valve to the opposite ends of the low-pressure cylinder, where it expands and propels the large piston, and in the next stroke passes through a circular groove in the centre of the valve, and is discharged through the exhaust port and exhaust pipe. The same operation takes place in both ends of the cylinder, the steam from the front of the high-pressure cylinder propelling, by its expansion, the piston in the back end of the low-pressure cylinder, and the steam from the back end of the high-pres-

sure cylinder propelling by its expansion the low-pressure piston from the front end.

The effect of conducting the different grades of expansion in separate cylinders is to avoid loss of heat from the steam conducted away by the cylinder and consequent reduction of force and waste of power.

The reason of this is obvious when it is considered that the temperature of steam lowers as the expansion progresses to lower pressures, and where the expansion takes place from the highest pressure to the lowest in the same cylinder, an undue portion of the heat of the high-pressure steam when admitted to the cylinder is expended in heating the cylinder above the lower temperature, resulting from the lower pressure steam expanded in it, and discharged from the preceding stroke.

In the compound engine the variations of pressure and attendant temperature in each cylinder is less, so that the absorption of heat from the steam by the cylinder is diminished.

Above and beyond this, a non-compound locomotive engine does not cut off steam and realize any economy by using it expansively, unless the engine driver adjusts the reversing bar and connected link motion, so as to cut off the steam at an early age in the piston stroke.

To enable a locomotive engineer to start, it is needful to adjust the link so that steam will reach the cylinder from the boiler nearly to the end of the piston stroke, motion of the engine being established, the link and the reversing bar being shifted towards a central position, and the throttle wide open, steam at high pressure enters the cylinder, is cut off early in the stroke, and expands to the end. This is troublesome where stops are frequent and is often neglected.

In a compound engine, on the contrary, the expansive working of the steam is compulsory, and does not depend so entirely on the attention and care bestowed by the driver.

The steam of boiler pressure flowing into the high-pressure cylinder of the compound engine further in the stroke than it does in the non-compound, a less reduction of

pressure occurs during the early and middle part of the stroke, which is true of all compound engines, and is here referred to as distinguishing the operation of compound from non-compound engines. It should here be borne in mind that it is essential in locomotive engines that the piston should near the termination of its stroke meet an elastic resistance to arrest the momentum acquired during the middle part of the stroke, or otherwise it would discharge such momentum in the crank pin and shaft, and impair or break them—this also is true of both compound and non-compound engines, and, excluding the latter part of the stroke from consideration, the force imparted to the crank pins throughout the stroke varies less in a compound than in a non-compound locomotive working expansively.

The proportion of lineal motion of the piston, to rotative motion of the journals of both the shaft and the crank pin is greatest near the centre of the stroke so that with higher pressure near the centre of the stroke than at the end, the transmission of the force of the steam to the shaft and wheels is attended with less waste of force in journal friction, a statement which can be readily verified by a comparison of indicator tests with brake tests upon the two classes of engines as employed in stationary service.

A by-pass pipe connects the opposite ends of the high-pressure cylinder, and, close to the points of insertion into the cylinders, is provided with valves controlled by the engineer, which are opened in starting the engine so as to permit steam to reach the low-pressure cylinder before motion of the pistons commences. These valves are closed during the normal working of the engine and by their use the engine starts promptly and readily.

The relative effects of the two modes of operating are shown in diagrams taken from both types of engines. In the non-compound engine, the pressure diminishes from an earlier point in the piston stroke, whilst in the compound engine it continues much further in the stroke with better mechanical effect.

The valves in the Vauclain engine examined by your committee were fitted with simple ring packings inserted

by springing them into grooves turned in the plug, and expanded by their own elasticity. There was very little, if any, force required to reverse the engine, when the throttle was open and full steam pressure upon the valve. In this respect it compares favorably with other engines, which require either the steam to be shut off before the reversing, or else a steam operated reversing gearing to be used.

For the performance of the same amount of work, the Vauclain compound engine requires less steam than the Standard engine, and therefore maintains steam pressure more easily, and has, after several months' use, demonstrated the most satisfactory running upon heavy fast passenger service and has repeatedly, during the tests by Mr. Barrus, run at the rate of a mile in forty-eight seconds.

The exhaust does not appear to be so noisy or with such strong impulses upon the draft, but at all times furnished all the draft required for combustion.

This engine rolls easily when cutting off close or with the reversing lever near the central position, and avoids the resistance of the piston to motion experienced in other engines in like adjustment.

The performance of this engine shows a decided economy in fuel, with a diminished requirement for feed water for the work done, the average fuel saving in four round trips between Philadelphia and Washington being very nearly fifteen per centum (within one-tenth of one per cent.). This, it should be borne in mind, is in competition with the best procurable engine, expanding steam in each single cylinder, having precisely the same steam generating apparatus.

The Vauclain compound locomotive for freight services, shown in accompanying illustration, has been tested upon the Pennsylvania and upon the Lehigh Valley Railways, and the diagrams and tabulated results of the tests are printed herewith, since which time the same engine has made a trial trip from Philadelphia (Belmont Station), to Reading, with an unusually large train, to which trip the entire Committee on Science and the Arts were invited, and several members made the journey and participated in the tests. A series of diagrams were taken upon this trip by Mr.

Shaw, of this committee, and Mr. Kenneth Rushton, copies of the diagrams are also printed herewith.

It will be observed in the diagram last referred to, that the exhaust line or piston resistance lines are marked in dotted lines and reversed in direction from the diagrams so that the eye may readily appreciate the difference of pressure operative upon the opposite sides of the piston at every point of the stroke, such dotted lines being reversed or transferred over, ordinates from the back pressure lines to the steam line will represent the difference between propelling force of steam and back pressure, or the net operative force transmitted to the piston.

In the tests made by the Vauclain compound engine very little of fuel or cinders accumulated in the smoke box as compared with the standard or non-compound engine and no sparks were observed to escape from the chimney.

The compound locomotive engine is at present such an innovation in railway practice as to command general interest and attention, and, to your committee, appears to require for a clear understanding of a report on the merits of the particular invention under consideration, that a review of the state of the art should be submitted therewith, to show the reasons which govern your committee in forming their conclusions upon the merits of the applicant's invention and facilitate intelligent action upon the report. Although well aware that such a review of the state of art is unusual, your committee are of the conviction that it is necessary and fully justified by the importance of the subject and worthy of both the labor of making it and of your attention in considering it.

They have accordingly prepared a concise abstract of each of the patented compound locomotive inventions of record in the British and United States Patent Offices, which they herewith submit, noting the characteristic peculiarities of each and showing a copy of the prominent figures of the drawings of each patent.*

* This abstract of state of art embraces fifteen pages of text besides several hundred figures of illustrations, and is too voluminous to insert in this journal. It is accessible in the Library of the Franklin Institute, together with copies of all the data before the committee and full copies of all patent specifications and drawings examined by the committee.

Date.	No. of Trip.	Railroad.	No. of Cars.	Weight of Train.	Time Consumed.	Time Detained.	Running Time.	Coal Burned.	Water Evaporated.	Coal per Car Mile.	Water per Pound Coal.	Coal allowed by R. R. Co. per Car Mile.	Engine Numbers.	Type.	Locality.
				tons. cwt.	*hr. min.*	*hr. min.*	*hr. min.*	*tons. cwt.*	*tons. cwt.*						
May 13,	1	L.V.	29	257 10	1 20	— 20	1 —	— 17	6 16	5·4	8·00	—	595	Compound	Sugar Notch to Fairview.
May 13,	2	L.V.	32	284 2	1 31	— 11	1 20	— 18	7 6	5·4	8·11	—	595	Compound	Sugar Notch to Fairview.
May 14,	3	L.V.	32	295 14	1 11	— —	1 11	— 19	6 18½	5·5	7·28	—	595	Compound	Sugar Notch to Fairview.
May 14,	4	L.V.	32	295 14	— 59	— —	— 59	2 1	8 7½	11·9	4·08	—	458	Wootten	Sugar Notch to Fairview.
May 15,	5	L.V.	32	295 14	— 50	— —	— 50	— 13	6 11	3·7	10·0	—	595	Compound	Sugar Notch to Fairview.
May 15,	6	L.V.	36	319 6	1 4	— —	1 04	— 14½	6 17	3·7	9·4	—	595	Compound	Sugar Notch to Fairview
				net tons.				*pounds.*	*pounds.*						
May 17,	7*	P.R.R.	$E^{50\ C.}_{90\ H.}$	563 C. 1022 H.	8 0	2 33	5 27	11,800	80,925	3·5	6·8	4·6	595	Compound	Philadelphia to Harrisburg.
May 18,	8	P.R.R.	*E*80	880	9— 5	1 32	7 37	13,000	125,330	2·5	9·6	4·6	595	Compound	Harrisburg to Altoona.
May 19,	9	P.R.R.	*E*27	338			No record on	account of	detentions.				595	Compound	Altoona to Gallitzin.
May 19,	10	P.R.R.	*E*40	404	1 22	— —	1 22	2,950	20,900	12·2	7·0	—	595	Compound	Altoona to Gallitzin.
May 20,	12*	P.R.R.	$L^{65\ M.}_{69\ H.}$	2483 M. 2654 H.	11 15	3 10	8 05	9,150	67,083	1·04	7·33	4	595	Compound	Altoona to Harrisburg.
May 21,	14*	P.R.R.	$L^{66\ C.}_{30\ P.}$	2425·4 C. 1053 P.	10 30	2 47	7 23	9,100	68,890	2·07	7·5	4·6	595	Compound	Harrisburg to Philadelphia.

* Trip No. 7 consisted of 50 cars, Philadelphia to Columbia, and 90 cars, Columbia to Harrisburg.
Trip No. 12 consisted of 65 cars, Altoona to Mifflin, and 69 cars, Mifflin to Harrisburg.
Trip No. 14 consisted of 66 cars, Harrisburg to Columbia, and 30 cars, Columbia to Philadelphia.

The construction of the Vauclain engine cylinders, valves, guides and crossheads, permits of their easy adaptation to the frames of existing Standard engines, and allows such diameters of low-pressure cylinders as to derive the best effect from the expansion of steam, a feature inadmissible in engines of the Hudson type, known popularly as Worsdell's engine, having two unequal cylinders, one on each side, as shown in the diagram on frontispiece, marked *Fig. G.*

This diagram shows above, the position of the cylinders of a Standard engine, and those of a Hudson* or two cylinder compound engine, annular cylinder engine (F. W. Johnstone's), and those of forms of the Vauclain engine, with the lines of limitation of width drawn upon them, all being of equal capacity of piston duty.

It will be seen that the Hudson low-pressure cylinder, whilst having its flange close to the frame, projects six inches beyond the lateral limit of 9 feet 3 inches and any reduction of the diameter of the low-pressure cylinder, impairs both the economy and capacity of the engine.

The Vauclain engine is applicable to the framing in general use upon American locomotives.

All parts of it are of simple and substantial construction and easy of access for lubrication, inspection and repairs.

It can be applied to locomotives having outside cylinders without increasing the entire breadth of the engines at the cylinders beyond the restrictions made necessary by bridges, tunnels and trains upon parallel tracks.

The transfer of steam from the low to the high-pressure cylinder is effected by the shortest practicable conduit. The valve construction is simple and, being balanced, requires a minimum of force to work it, irrespective of the steam pressure upon it.

The distribution of force upon each side of the engine is equal.

Each side of the engine is capable of working, when the

* The two-cylinder type of compound engine, popularly known as the "Worsdell," was first patented by Mr. W. S. Hudson, of Paterson, N. J. (Superintendent of the Rogers Locomotive Works), March 11, 1873.

other is disconnected, and when so operated, can produce a draft sufficient to maintain effective steam generation for running purposes, a feature of decided importance in cases of accident disabling the engine of one side.

The engine always starts promptly and steams readily with the diminished exhaust pressure, the volumes of the exhaust being greater than with the Standard or non-compound engine and occurring twice as often in the revolution of the shaft, as in either the Webb or Hudson type of engine.

It is not pretended that this compound engine imparts any new properties to the steam that is used in it, so as to surpass other well-proportioned compound engines, in degree of expansion and consequent economy of steam, but that it does diminish the clearance space between the high- and low-pressure pistons, and promptly proceeds with the expansion in the low-pressure cylinder, whilst in other types of engines the exhaust from the high-pressure cylinder must be retained in a receiver, to await the opening of the valve admitting it to the low-pressure cylinder.

In engines of the Hudson type, with the cranks at an angle of 90° this is about one-half of a stroke of the piston. In the Webb engine, during each revolution, there are four deliveries of steam from the high-pressure cylinder, to the receiver or pipe leading to the low-pressure cylinder, while there are but two deliveries of steam to the low-pressure cylinder and since there is no mechanical connection to transmit motion of the wheels driven by the high- and low-pressure cylinders, except the adhesion of the wheels to the rails, there is no regular timing of the exhaust of the high- and low-pressure engines, for they are, to all intents and purposes, in mechanical connection, independent of each other, except in steam supply.

The Vauclain engine, on the contrary, takes steam immediately from the high- to the low-pressure cylinder, and the two pistons being connected, move together and require no receiving chamber in which to store the steam and in which the steam expands without useful effect.

Claims are urged for engines having a receiver exposed

to heat from the products of combustion in the smoke box for reheating or superheating the steam, but when it is considered how much steam is to be heated, how little time it is exposed to the heat, and how low the temperature in the smoke box, with the gentler exhaust from the low-pressure engine, your committee is not impressed with its importance. The loss by expansion in the receiver is apparently as great or greater than any possible gain by the reviving action of the heat of the receiver.

A practical confirmation of the merits of the invention, as it impresses your committee, is to be seen in the rapid adoption of the engine by the roads that have tried them or observed them carefully as used by others. The number of engines in use and ordered for use after examination and tests, showing the avidity with which railways adopt them, confirms your committee in their conclusions as to the merits of the invention.

As compared with the two-cylinder compound of the Hudson type, the Vauclain is two distinct engines, having no connection with each other but the driving axle, and when either engine is disabled, the other can be operat,ed and the connected train moved, whilst with the Hudson or Worsdell type of compound, the two engines are necessarily interdependent, and when either is disabled, the exhaust through one cylinder only is inadequate to produce draft sufficient to generate steam.

The same difficulty appears in operating a single cylinder of the three-cylinder or Webb type of engines.

Whilst both the Hudson and Webb type of engines are capable of showing economical results, as operated in Europe, under prescribed favorable conditions, in the control of their inventors, they do not appear to meet the varied requirements of service demanded upon railways as operated in this country, and it has not yet been practicable to adjust the traffic to engines of fixed capacity for economic work.

Your committee, in conclusion, find that in view of the state of art, the Vauclain compound locomotive is a distinctly new and original type of locomotive. It is the most

marked departure from the usual construction of engines, that has elicited general satisfaction wherever introduced, and in view of the reliable and satisfactory performance in service under the largest variations of conditions, immunity from total disablement, ready adaptability within limits of space incapable of accommodating other compound engines, and general applicability to and utility in railway service, it is, in the opinion of your committee, deserving of recognition by the award of the Elliott Cresson Medal of the Franklin Institute, which they hereby recommend.

S. Lloyd Wiegand,
Luther L. Cheney,
William L. Simpson,
John E. Codman.

Adopted, June 3, 1891.

S. Lloyd Wiegand,
Chairman of Committee on Science and the Arts.

VAUCLAIN'S DRIVING- AND TRUCK-WHEEL CENTRES.

[No. 1,620.]

[*Report of the Committee on Science and the Arts.*]

The sub-committee, No. 1,620, of the Committee on Science and the Arts, to whom was referred for examination and report the improved method of making wrought-iron driving- and truck-wheel centres, patented by Samuel M. Vauclain, of Philadelphia, and practised at the Baldwin Locomotive Works, respectfully report that they have examined the said invention and the apparatus for operating it, and have inspected the product, specimens of which are herewith produced, and find as follows:

The invention is the subject of two Letters-Patent of the United States, respectively numbered and dated 408,056, July 30, 1889, and 420,842, February 4, 1890, granted to the inventor, Mr. Samuel M. Vauclain, of Philadelphia, Pennsylvania.

The object of this invention is to produce strong wheel centres of wrought iron, expeditiously and cheaply, of the

forms which theretofore had only been practicable to form by casting, and which had, as all iron castings have, a liability to fracture.

To concisely describe the process, they are drop-forged or swaged from parts previously rough-shaped, which are not only swaged or die-forged, but are simultaneously welded together.

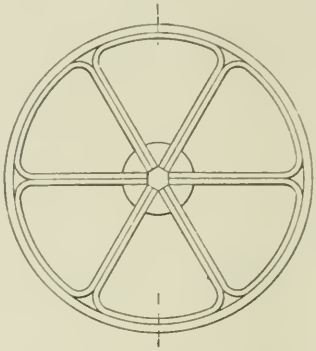

FIG. 1.

The invention is well described, and is illustrated in the specifications and drawings of the letters-patent, which are here reproduced, showing the parts as made in the rough, preparatory to assembling, heating and welding, and the finished wheel centres and sections thereof.

The parts are as follows: A cylindric band, shown

FIG. 3.

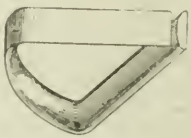

FIG. 2.

FIG. 5.

separately in *Fig. 4*, which forms the rim of the wheel shown in *Fig. 1*, a triangular bent piece, having a convex inner surface, the curved side, forming part of the rim, and each straight side, forming one-half of a spoke, shown in *Fig. 1*, and hub pieces, shown in *Fig. 3*, having radial grooves, into which the inner ends of the spokes are placed, it being

understood that the two contiguous parts enter into and form each spoke. The parts are placed together, as shown in *Fig. 1*, and small triangular drop-forged pieces shown separately in *Fig. 5*, are placed in the spaces left between the rim and the contiguous bends of the triangles.

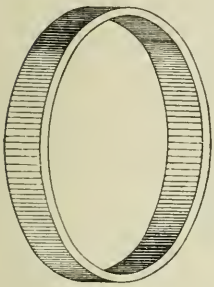

FIG. 4.

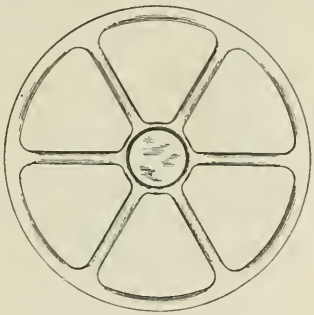

FIG. 6.

FIG. 7.

The parts, as assembled, are placed in a furnace and heated to a welding temperature and then placed in a bottom die, shaped like one-half of the finished wheel, and secure upon the anvil of a direct-acting steam hammer.

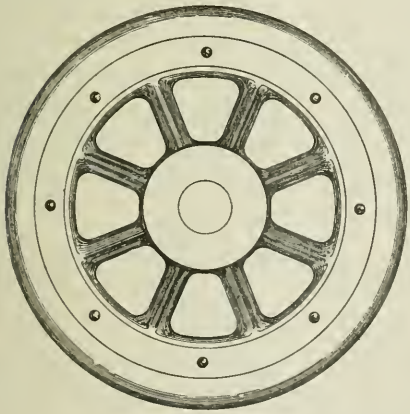

FIG. 8.

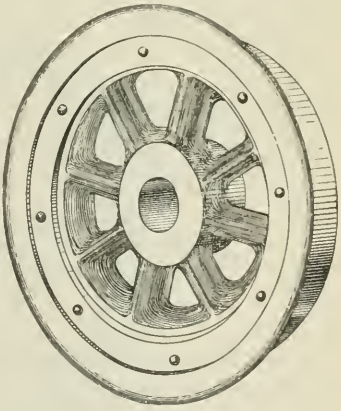

FIG. 9.

The upper die, which is a counterpart of the upper side of the finished wheel is attached to the ram of the steam hammer and guided so as to register with the lower die, is then forced down upon the hot metal and forces and welds the parts together, at the same time swaging them into the

shape of the wheel depicted in *Fig. 6*, and of section as shown in *Fig. 7*.

Any superfluous metal finds vent between the faces of the dies in the form of a thin fin or beard, which is easily removed with chisels. As above described, the wheel centre produced is a truck wheel having spokes of elliptic cross-section and are shown with the tires applied in *Figs. 8* and

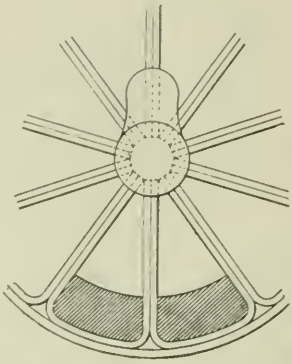

FIG. 10.

FIG. 11.

9. For driving wheels, as at first made, bosses of metal, of the proper shape to form the crank, with grooves to fit over the spokes, were used, together with blocks of metal laid between the opposite spokes to form the counterbalance and corresponding recesses formed in the dies to shape them into the form shown in *Figs. 10* and *11*. The weight of the counterbalance was thus determined at the time of the forging,

FIG. 12.

FIG. 13.

As further improved and described in the letters-patent, the counterbalance is made hollow, of two parts, each shaped as a segmental box, with notches in the edges to fit over the spokes, as shown in *Figs. 12* and *13*, and the metal for the crank boss introduced in similar manner, and the wheel produced is as shown in *Figs. 14* and *15*, with a hollow counterbalance, which was afterward adjusted in weight by the introduction of melted lead to suit the varying require-

ments of differing weights of connected parts in the engines, to which the wheels are applied. A finished driving wheel fitted with a tire is shown in *Fig. 16.*

The dies for swaging the wheels are made with a flat

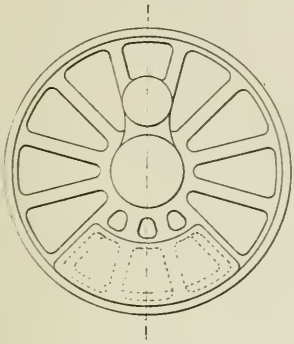

Fig. 14.

Fig. 15.

bottom and rim, forming a bed into which the parts for the shaping of the spokes and rim are fitted in separate segments, the central boss and crank boss dies being of steel and the other parts of cast iron, so that by changing only a portion of a die, wheels of different proportions of hubs and

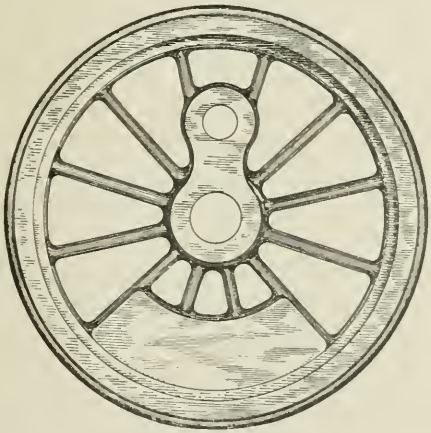

Fig. 16.

length and diameter of crank may be made, a feature of great importance when the variety of sizes and proportions demanded for the numerous classes of engines is considered in conjunction with the weight and cost of the dies.

The wheels as forged are soundly welded throughout, as is shown in the specimens submitted, cut in every part, so as to expose the parts involved in every weld.

They have all the desirable features of shape and convenience of adjustment in counterbalancing that heretofore were procurable by cast wheel centres, and such strength as to be practically indestructible.

In point of cost, they compare with cast-iron wheel centres as the price of rough iron bars or muck bars compare with the best pig iron, the cost of heating, welding, drop-forging and dressing-off of fins being somewhat less than that of moulding, casting and cleaning the iron castings.

Experience has demonstrated that sound and reliable welding is had with fins of less than one-fourth inch thick—more nearly one-eighth inch in fact, and with a variation in weight of the wheels of less than two per centum.

Your committee are well aware that wrought-iron locomotive and car-wheel centres have been made wherein segments of the rim were forged each with a spoke and segment of the hub and the several segments of the rim welded together. This was tedious and expensive work and required considerable dressing about the points of welding to make any presentable finish of the work; also that wheels having spokes and rims made up of triangles and rims riveted together, with hubs formed on the inner end of the spokes by casting have been made. None of these, although expensive to make, are comparable in strength, durability or finish, with those shown by this inventor.

Your committee are of the opinion that the Vauclain wrought-iron wheel centres are a valuable improvement in the art, contributing alike to economy and safety of railway service, and as such deserving of recognition by the award of the John Scott Legacy Premium and Medal.

LUTHER L. CHENEY, COLEMAN SELLERS, JR.
JOHN L. GILL, JR. JOHN HALL,
S. LLOYD WIEGAND.

Adopted, May 6, 1891.

S. LLOYD WIEGAND,
Chairman of Committee on Science and the Arts.

POSSIBILITIES OF APPLIED SCIENCE.

By Oberlin Smith.

[*A lecture delivered before the Franklin Institute, February 16, 1891.*]

[*Concluded from vol. cxxxi, p. 434.*]

The next general factor in the civilization of the race, which appears in my classification, is *trade*, or traffic, and, in its comprehensive sense, this term should include manufactures, which, abstractly considered, begin at the field and the mine, and consist simply of the buying and selling of labor. This field is, of course, too large to attempt to harvest in detail in a lecture like this. It may be well, however, to touch upon a few salient points, in addition to those improvements mentioned under other headings, which will inure to the benefit of traffic, such as better railways, ships, etc.

One improvement that we may expect in manufacturing of all kinds, is the standardizing of the articles made, both in regard to quality of material as well as in design and dimensions. How this can be universally brought about I leave for the students of social science to determine—in view of the fact that some unification of interests, and some submission to a central authoritative power, would be prerequisites. That a great deal of it should be done, is a fact patent to every engineer. Such standardizing not only cheapens goods, but makes them better and facilitates the interchange of parts where modifications and repairs are desirable.

Among the improvements which I think are destined to appear along with other economies of ordinary commercial life is a considerable amplification of the "automatic-payment" idea, which started with the fare-box in omnibuses and street cars, and has become so popular in the way of nickel-in-the-slot machines, of all descriptions, and for all purposes—from weighing a baby to lighting one's cigar.

The primal idea in all these contrivances is simply to save the time of a salesman, and I think we are destined to see the principle applied to many things where its use is now almost inconceivable. Very possibly we shall have special coins prepared for such work which will in themselves act as keys to unlock the devices which they seek to enter. The development of this idea may give us tickets, to carry as coins, which will let us into a ferry-house or railway station without the danger of irritating the nerves of a guardian angel tending its gates.

In our counting-houses, we are doubtless destined to use much more machinery than at present. Our typewriters will be improved, let us hope into accuracy and noiselessness; we shall use mechanical and electrical calculating machines for adding our ledgers, and the phonograph will very likely relieve our stenographers of their most arduous duties. This latter machine is, of course, at present in a somewhat embryotic state, but it seems to me that its future prospects are almost boundless. The wonders which it is to accomplish have been so often said and sung by magazine writers and by scientists, that it is scarcely worth while to enter into all the probable details here. In general, the chief commercial uses which are likely to be made of this greatest discovery of the nineteenth, or any other, century will be not only the dictation of letters, to be afterwards printed or written, and the mailing of the records direct, for use in other people's instruments, but the keeping of business records and statistics. Not speaking now of its domestic, artistic, literary and historical uses, I will only say further that it probably is destined to occupy a very important field in the taking of legal testimony—as a stenographer that "cannot tell a lie." I have called this wonderful machine a "discovery" because, in its primal stage, it was this, rather than an invention. The accomplished Edison found out, for the first time in the history of the world, that articulate sounds, with all their delicate individualities, *could be* translated into simple mechanical undulations—and this by machinery of ideal simplicity. The invention came afterward, and must still

go on, further and further toward perfection. This perfecting process will very likely bring about devices whose action will be electrical rather than mechanical, thus securing a delicacy otherwise unattainable. In this form it may be made a part of a self-recording telephone—so that it may be talked to at any distance.

Boundless also seem the future possibilities in regard to the telegraph, the telephone and those various tel-something-or-others which are to come, whose function it will be to transmit our handwriting, our printing and our pictures; and, in a higher state of development, perhaps views of our faces and surrounding objects. Indeed, who knows but that the senses of touch, taste and smell may yet be transmitted—by politeness of the same mysterious Mercury who now carries our voices over thousands of miles of forest, sea and plain? In the telephone itself, we fondly look for some improvement, at least those of us who are amateurs. The ideal telephone would of course be international, and its current as good a voice transmitter by ocean as by land. We must look to science to cure it of its *mal de mer*, and to make it perform its functions on land so that a part at least of the conversation will consist of something else but "hellos!" We must have it so good that no sound can be heard but the voices of the two individuals who are using it for the time being, and so cheap that it can be in every house having any pretensions to affording the ordinary decencies of life. May we not hope sometime to have it so arranged with regard to its exchange system that any user can, by the moving of a pointer to some number, or combination of numbers, put himself in communication with any desired correspondent in any part of the civilized world? And may this not happen *while* others are using the same wire, and without interference? All this will doubtless seem to the "practical" electrician of to-day as the rhapsody of an enthusiast, but stranger things than this have already happened, and there is no knowing what brilliant results may from time to time be achieved as we follow out, more fully than heretofore, the general principle of running different kinds and phases of currents through the same wire

at the same time—on top of one another, so to speak. The embodiment of this principle has already made famous an Edison, by the invention of quadruplex telegraphy. It has enabled us to send an "induced" message, in train-telegraphing, over a wire through which ordinary messages are passing at the same time. By it, a Gray sends a dozen musical tones of different pitches through a wire in which they don't get mixed up at all.

In regard to *travel*, we perhaps have before us more brilliant possibilities than in almost any other field of human achievement. For rapid land-travel we shall probably have some modification of our present railways, which will be as far ahead of them in refinement of construction and action, as is a polished lady's bicycle, of rubber and steel, beyond the clumsy wooden wheel-barrow of the navvy. This comparison I have made before in an article upon "Reform in Railway Construction," which was published by the *Forum*, in its issue of January last, and to which I refer any one interested, for my ideas on this subject, in detail. It seems to me beyond question that some succeeding generation, perhaps the next, will travel at a speed of somewhere between 100 and 200 miles per hour. The motive-power will probably be electricity, applied to the axles of the cars themselves, which cars will be incombustible, comparatively non-smashable and of such low specific gravity as not to carry some five tons of dead weight for each passenger, as do our present Pullman trains. There will be some electric, automatic, block-system to prevent collisions, and the cars and track will be interlocked with such harmonious relations that derailment will be impossible. We shall not then drag cars made purposely heavy, so that they may ballast down narrow wheel-flanges to their function of keeping us out of eternity. They will of course be warmed and lighted by the same current which drives them, and will, let us hope, be in direct telegraphic and telephonic communication, accessible to the passengers, not only with all the stations along the line, but with other cars running thereon. A further development of this system may result in each train and station having a chart of the road upon which will move,

automatically, dots, representing all trains, thus enabling many eyes at once to constantly watch for any dangerous contiguity thereof.

Should we by that time have learned to produce our electric currents from the coal direct, the cost of travel will be reduced to a figure marvellously low. This will be due not only to the small cost of motive-power, but also to the enormous increase of the travelling habit, due to the comfort, safety and speed attainable.

There is no reason why some of the methods which will so facilitate travel upon railways should not be extended to ordinary wagons, omnibuses and carriages—as also to tricycles and bicycles. All of these can advantageously be run by electric motors—providing we can get storage batteries sufficiently light, primary batteries sufficiently cheap, or line conductors sufficiently convenient.

In regard to water travel, the improvements that another generation may expect in our sea-going ships will consist, first of all, in absolute safety from fire and foundering, due to proper metallic construction and the division of the hulls into a sufficient number of air-tight cells in addition to its general division into large separate compartments. This latter point we have nearly reached now, but, as was proved last year in mid-Atlantic, not close enough to prevent the passengers on one of our safest and fastest steamers from indulging in profound meditations upon a Future life, during the three or four days succeeding the opening of a small hole in the ship's bottom. Had she been cut in two by a sister ship we probably should never have heard of the meditations in question.

In the second place, these ships of the future will probably be driven by electricity, through the means of a simple rotating armature fixed directly upon the shaft of the screw itself; that is, if the screw (or screws) still remains the best method of propulsion. Nothing simpler or smoother in its action than this can be imagined, and it will certainly be a welcome substitute for the vast mass of boilers, engines and pumps which now fill so large a part of the hold of a vessel. The source of electric current for driving the motors

of these three- or four-day "Atlantic liners," will probably be either storage batteries, placed in the extreme bottom and along the whole length of the hold, where they will serve as excellent ballast, or else the current will be generated by some direct process from coal or other fuel, either burned or otherwise chemically disorganized, during the passage. The latter method of course is after the similitude of our present primary batteries, but who can say that we may not after all revert to this original method of producing a current, when we have learned how to do it without using such expensive materials as zinc, for instance, for fuel. If, on the contrary, we use storage batteries it will be because we have by that time learned to make them enormously lighter in proportion to the power stored than we can now do, the present weight of some of them being over 100 pounds for each horse-power per hour. This is bad enough, but we obviously must not make a direct comparison with (say) two pounds of coal per horse-power hour, because the weight of furnaces, boilers, water and part of the engines can be omitted. The recharge of these batteries would of course take place during the time that the ship lay at her wharf, and could go on all day and night simply by connecting two wires to a pair of screw-cups in the ship, such screw-cups being her only visible relation with the-powers-that-be on shore. All this is now habitually done with scores of small pleasure boats on the Thames, but they cannot possess a very high efficiency.

The same current which drives our hypothetical ship will, of course, be available for loading and unloading cargo, pumping water, blowing and sucking air, hoisting sails (if there be any), loading cannon (should such a barbarism have survived into the electrical age), sounding signals, communicating with other ships by some system of water telephoning, warming the ship and cooking the dinners; also for lighting the ship with a daylight brilliancy, both below and above deck.

What we shall do in the way of submarine boats, is, of course, a matter of conjecture; but should they for any reason be desirable, either for purposes of war, or for

getting a little way under the surface to avoid sea-sickness, we can hardly doubt that our inventors will contrive ways to manage them safely. We have beaten in speed and endurance the animals on land; why should we not the fish within the sea? Jules Verne, in playful spirit of romance, has pictured such a boat, but it seems not beyond the bounds of possibility that our inventors will sometime, in this respect, out-distance his wildest speculations—especially as we have already made small ones which have remained for hours below the surface.

In regard to the construction of our future boats, we can only guess; but it seems not unlikely that science will develop some less crude method of building such a complex structure as the hull of a great vessel, with all its decks, bulkheads and other partitions, than the present piling together of hundreds of thousands of pieces, in the shape of plates and rivets and bars, that are obliged to be much heavier than would be the case were they not weakened by the very means used to hold them together. Possibly we may by that time develop some practical system of welding as a substitute for riveting, or (who knows), perhaps we may learn to make any metallic structures we desire, either small or great, in one piece complete, by the process of electro-deposition! These may be radical ideas, but who can say they are too much so, in the light of the very recent inventions for welding up the shells of large boilers, and for electro-depositing large balls and tubes?

The material of these boat- and ship-hulls of a coming age, whether made into one piece by riveting, soldering, welding, casting or depositing, may still be steel, as now. More likely, however, some better and less corrodable alloy will be made available. Very possibly its composition in large measure will be aluminum.

As before remarked, we have beaten the beasts upon the land, and, in some respects, the fish within the sea. Does not analogy tell us that sometime we shall also have beaten, in their own element, the birds of the air? I am aware that flying-machines, from the time of Daedalus down to

that of Darius Green, have been a butt of ridicule for all sensible people, and the pet weakness of many so-called cranks. It is nevertheless true that a bird is simply a machine, and when we properly learn the principle upon which he flies, and learn also to store as much power within a machine of proportionate weight, we shall be able to fly just as well as he does—or better. We must, however, abandon the notion of carrying a great bag of gas with us to form an obstruction against the air, and depend upon the same principles as does the bird. We have been amusing ourselves with gas balloons now for over a century and have gotten very little further along than did Montgolfier at the start. We occasionally paddle them about a little upon a still day, or in an exhibition building. Is it not time for us to stop all such nonsense and give our attention to scientific study and experiment? A lark couldn't fly carrying an inflated pillow-case. We cannot stop the wind blowing where it listeth—and taking gas-bags along with it.

Of course, we must accept the fact of the inherent danger of even a good flying-machine, in regard to collision and the possibility of falling should the machinery get out of order. Just as does a bird relinquish all hopes of happiness when a bullet, or another bird, or a stroke of heart-disease kills him in the air, so must our future aëronauts expect a great calamity should a collision occur in going rapidly at a high elevation. Possibly, however, the falling part of the danger might be modified by some system of self-acting parachutes. Here, too, with our mechanical birds, as in case of our future ships, we shall probably depend upon stored electric power for driving, lighting and warming, and shall construct in the lightest possible manner, with the lightest possible metal and other materials.

Learning is the next general subject in my list, but a difficult one in which to prophesy reforms due to inventive genius. Among other improvements which will assist in teaching us how to teach, and by which we may learn how to learn, is a more complete and systematic adoption of the general principle of standardization, making more uniform our systems of learning in our schools and colleges.

In classical education this has, of course, already been done, but in the comparatively new conditions of scholarship, as pertaining to the study of science, many changes for the better will doubtless be made.

Among the improvements of the future that we may expect to aid us in scientific scholarship will be some international unification of weights and measures, which must be even better than the French system ; a spelling reform which will greatly lessen the difficulties of mastering language and save a great deal of printer's ink, etc. Another thing that we scarcely realize now is, I think, the use that could be made of the phonograph or some similar instrument, as a means of standardizing language, not only in different provinces of a country where a given language is spoken, but throughout different eras of time. This would go beyond all pronouncing dictionaries, which are, withal, only able to define the sound of a word or letter by referring to an assumed value for the character representing it. This assumption may, by sufficient care, be standardized for different places, but not for different centuries of time. Can words express the value that would now be set upon a few "phonograms" spoken in Rome and Athens 2,000 years ago —or a few more by Chaucer and Will Shakspere?

Another possible source of knowledge beyond our present dreams may consist in the invention of instruments by which we may hear sounds which are now too low, or too high, in the musical scale for our ears to recognize. Who can say what hidden stores of knowledge are lying fallow in these realms of sound that are all around us, but to which our ears are deafened.

In the field of *art*, meaning thereby the fine arts, we can hardly prophesy much change except that due to the natural evolution of the race itself. From this source, however, we must expect a greater love for, and more appreciation of all beautiful things. As this feeling grows it will demand that all streets and buildings in our cities be made beautiful ; that our non-urban landscapes be not ruined by ugly houses and factories, and by topographical outrages in the way of crude cuttings and embankments for public works, left bare

of grass and trees, and cut to contours antagonistic to æsthetic considerations.

If one dare in this connection to mention photography, which perhaps I will venture to do, on the risk that there are no artists present, I will say, that the much-wished-and-hoped-for discovery of photographing in natural colors seems to me entirely within the pale of possibility—although I am not going to tell you this evening just how it is to be done. We have already heard rumors in the air of a desideratum of this kind, but a perfect system is still probably afar off—one, I mean, that will be a cheap and simple process, and that will give all the natural colors of the object, pictured with every intermediate shade true to nature.

In regard to the future possibilities of *medical* and *surgical* science, as bearing upon health, the last subject upon my list, we can form but little conception. My own opinion, formed from judging by analogy, is that there are grander possibilities in this field than any of us can realize. Recent improvements in antiseptic surgery go far to show that living bodies can be cut up in almost any way, and that nature seems to have ready a laboratory in which to put them together and repair them again to order. Such facts would seem to lead us to the belief that we are only on the threshold of the wonderful era that is to come. Just now we naturally turn to the brilliant discoveries of Koch, as further establishing a great principle governing the work of conquering our microscopic enemies, which principle was foreshadowed by Jenner, and ratified by Pasteur. Recent experiments also show that remedies purely chemical, applied scientifically, rather than in the empirical way in which drugs have been administered through the past centuries, will hold a leading place in the "curative engineering" of the future.

As in other departments of human knowledge, we can scarcely leave electricity out of the question in this. It is true that the so-called electrical treatment of the past, consisting of sending slight shocks through the muscles, may have benefited patients, perhaps chiefly by imagination;

but new methods of using the electric current are constantly being devised, such as, notably, the conveying of medicinal chemicals through living tissues by a process of electrolysis. Among other future developments we may fairly expect that a correct diagnosis of diseases and injuries will be much aided by some system of brilliantly lighting any part of the body. At all events, the advances in medicine and surgery during the last score of years have been so many and so brilliant, that the more sanguine of us may fairly feel justified in looking to science for the eventual alleviation of all diseases excepting old age itself. And who can say that we may not at some time conquer that?

The timid peep we have attempted to take into the secrets of Nature's Arcanum has been but a cursory one, and probably covers but little of the ground that we seek to investigate. Some of the results we have pictured in our minds may not turn out to be practicable at all. Others perhaps fall far short of what may prove easily attained realities. Many of them seem, to me at least, merely future certainties, which will materialize as fast as the world thinks it needs them—and is willing to pay for them. If even a few of the pictures I have drawn, may happen to serve as hints to discoverers and inventors regarding some of those things which will, in the coming generations, serve to make men happier as well as better, a worthy purpose will have been accomplished. To such investigators I would say: Press forward along every possible line of approach toward the grim fortress in which Dame Nature has intrenched her secrets. Do not fear departures too radical from conventional methods, and do not be afraid of being called "cranks"—only, do not *be* cranks. To avoid this, work within the pale of natural law—as far as it has yet been discovered. Do not try to find out for yourselves things that have already been established and recorded (even in the school text-books on physics) but accept certain facts and principles that a long line of eminent scientists and engineers have made clear. To capitalists, seeking a harvest from the field of applied science, I would

say: Encourage inventors, far more than in the past, but with more discrimination—that you may not purchase will-o'-the-wisps that try to controvert such well-established principles as, for instance, the conservation of energy and the gravitation of matter. To inventors and capitalists, jointly, I would say: Get together and plan your work systematically. The time has come when some organized scheme, for properly using the stored energy latent in your brains, on the one hand, and your money on the other, should be put into practical shape. You all need a clearing house, so to speak, where a general view of your valuable balances can be obtained, after deducting the rubbish due to the brainy man's poverty and crankiness, and the moneyed man's ignorance and credulity. Will one of the "possibilities" we have been talking about be some organization of this kind, taking shape as a splendidly endowed National University of Experimental Science—its faculty a board of mentors, carefully selected from the highest engineering and other technical talent of the land—its students a colony of investigators and inventors, admitted only after passing rigid examinations in the laws of physics and in mechanical sanity?

In concluding this somewhat rambling discourse, let me ask you to lift with me for a moment the veil that shadows the coming generations of our science-endowed race. Methinks I see a smiling land, where the topographical, the agricultural, the architectural, the electrical and, guiding them all, the æsthetic engineers have, unhampered, worked their will. The financial engineer has given them more than moral support, for, by the conservation of its energy—by having learned to avoid waste—the land has waxed rich. I see "things of beauty" everywhere, for we have learned to make for ourselves "joys forever" by allowing no vandal to mar our landscape with an ugly building, or fence, or road. Such of the railways as are above ground are raised above the highways upon artistically designed metal-work, and guide unerringly the feather-weight, rocket-like electric cars that shoot noiselessly by at frequent intervals. Buried wires convey to every farm-house, from distant water-fall or

mine, the vital current that warms and cools and lights them—that cooks their food and runs at will the machinery of the kitchen, the churn in the dairy or the organ and phonograph in the parlor. Without doors this same current has been taught "to plow, to sow, to reap, to mow"—to light the fields at night when needed, as well as to winnow and to thresh. Other wires give telephonic kinship with the world outside, and bring concert, sermon and opera from distant metropolis. On the asphalt highways, underlaid in certain lines, separate from the horse-tracks, with induction plates, glide tricycles and other low carriages of analogous light and elegant construction—their motors running at will when brought over the sunken wire-wound plates.

In our cities, I see like emblems of civilization, urbanized and intensified. Every street and lane delights the eye as a work of art—the buildings not only beautiful in themselves, but forced by some civic power into a co-relation of architectural harmony. Here, in the home of your famous Institute, the guardian spirit of your beloved Franklin has exorcised the tutelary demons of The-coal-smoke and The-cobble-stone, and smiles benignly upon a procession of shining vehicles devoted both to pleasure and to traffic, rolling silently upon their rubber tires over the asphalt pavements of the "New Philadelphia."

The UTILIZATION of the POWER of NIAGARA FALLS and NOTES on ENGINEERING PROGRESS.

By Coleman Sellers, E.D.

[*Amplified from the stenographic report of an address delivered at the stated meeting of the Franklin Institute, held May 20, 1891.*]

Jos. M. Wilson, President, in the Chair.

Dr. Sellers spoke as follows:

Mr. President and Members of the Franklin Institute:

It has been many months since I have had an opportunity to address the general meeting of the Franklin Institute, having been called away from the country to attend to the matter about which I will speak this evening.

The Falls of Niagara have always been looked upon as a wonderful work of nature and at the same time as a possible source of water-power beyond anything that exists that we now know of.

Niagara itself seems to be so situated in regard to the population of the United States, as to be a place to which manufacturers might naturally go. As a location affording abundant railroad facilities, close to the line where cheap labor can come to the manufactories, and also on the line of water communication from the Great Lakes themselves, and what is of much importance, near to the great markets.

The drainage area that supplies the water to the Falls of Niagara is something enormous. It can be scarcely realized until you see the figures that have been prepared by the Government of the United States in taking cognizance of the rainfall over one of the largest rainsheds of the country, and from other data as is shown by the following statements compiled from official records of the United States Government and published by the Cataract Construction Company with a map showing the location and the Great Lakes.

"The system of the great fresh water lakes, or inland seas, which drain through the St. Lawrence River into the Atlantic Ocean, extends half-way across the Continent of North America.

"The water surface of these great lakes, with the land sloping into them and contributing to the Falls of Niagara, has a total drainage basin of over 240,000 square miles, equal to more than twice the area of Great Britain and Ireland, about 40,000 square miles more than the total area of France, and more than fifteen times the total area of Switzerland.

"The length of the shore line of these lakes and their connecting rivers is about 5,000 miles.

"The fall of 326 feet between the water levels of Lake Erie and Lake Ontario occurs in the vicinity of Niagara Falls and is distributed as follows:

	Feet.
Five miles of rapids between Lewiston and lower Suspension Bridge,	100
Rapids between Bridge and the Falls,	10
Falls of Niagara,	160
Rapids immediately above the Falls,	50
Upper Niagara River,	6
Total fall,	326

"The Niagara River forms the boundary between Canada and the State of New York. The Falls of Niagara are twenty-three miles below Lake Erie, and fourteen and one-half miles above Lake Ontario. At the Falls the international boundary passes in the middle of the channel that forms the "Horse-shoe Falls," which are 158 feet high, and 2,600 feet wide. The other channel, in the State of New York, forms the "American Falls," which are 169 feet high at the eastern side, and 1,000 feet wide, both falls comprising 3,600 linear feet of water.

"At the Falls the river turns directly at right angle and flows through a gorge, the cliffs of which are 1,100 to 1,200 feet apart, with perpendicular walls rising 210 feet above the water, which has a maximum depth of 189 feet, and a width of from 800 to 900 feet.

"One mile above the Falls the river has a width of 6,000

feet. The extreme limits of variation in the depth of the river above the Falls is three and one-half feet, but these limits are very rarely reached. The ordinary variation is about one foot. Below the Falls the extreme variation reaches fifteen feet. Generally, a variation of one foot above the Falls is followed by a change of level of five feet below the Falls. These slight changes are of short duration and are due mainly to long-continued and violent wind or sudden great accumulations of ice.

"The average discharge of water at the outlet of Lake Erie into the Niagara River is estimated by some authorities at 265,000 cubic feet per second.

"The outflow of the lake basin is about half its rainfall. It has been estimated that if the average discharge of all the lakes passed through a river one mile wide, with a mean velocity of one mile per hour, such a river should have a depth of forty feet from shore to shore.

"The volume of water in the lakes, including Lake Ontario, is about 6,000 cubic miles, of which Lake Superior contains a little less than one-half. An idea of this existing quantity of water is given by the statement that the volume is sufficient, without additional rainfall, to continue the present flow of Niagara Falls for about 100 years, could it be generally exhausted by drainage.

"The flow of water at the Niagara Falls is, for all practical purposes, unlimited, never failing, constant and pure."

There are several reasons why the advantages of Niagara have never been used to any great extent, the chief being engineering difficulties necessitating the expenditure of large sums of money in anticipation of the power developed being taken up. In the beginning of this century it was in the wilds of the backwoods, and people who wished to see the Falls of Niagara had to go on horseback or on foot to reach it.

Perhaps the first traveller who wrote anything of interest regarding the Falls was Father Hennepin, who visited them about 1682, and he probably exaggerated, as his description hardly tallies with what we know of this wonderful work of nature. About seventy years afterwards a Dane visited it

and in an interesting letter to a friend in Philadelphia, which letter was published in the *Gentleman's Magazine*, London, he notes that certain changes had taken place in the great Falls, and it was his comments upon what Father Hennepin had written that gave us our first information that the Falls were wearing back, but it was not until quite recent times that any survey was made to show how rapidly or how slowly the wear was taking place upon the breast of the dam that forms this wonderful fall; now, however, the most careful surveys have been made and monuments placed, so that from this time forward we will know exactly the rate of recession that is taking place.

To bring you to the subject of the evening's discourse, I was in a New England town year before last spending the summer, and I was asked from New York to report upon the cost of transmitting power by electricity as compared to the cost of generating power by steam at any given location.

The gentlemen who had asked this question were those who had been busying themselves with the subject that had first been proposed by Mr. Evershed, one of the surveyors of New York State, who proposed developing the power of Niagara Falls on nearly the same lines that are now being pursued by the Cataract Construction Company for the Niagara Power Company.

I was asked to take up Mr. Evershed's scheme and having examined it very carefully I found that it was feasible, and that if 20,000 horse-power could be disposed of by rental out of the 120,000 horse-power that was talked of being used, a reasonable rental would pay the interest on the investment, not only on the plant that was necessary to develop the power but also of the land that would have to be purchased. On the basis of my report, which was endorsed by other engineers, a company was formed and the money secured to carry out the scheme, Mr. Edward D. Adams, of Messrs. Winslow, Lanier & Co., bankers, of New York, being made the President of the company.

Mr. Adams was in France for a short time last spring, and while there and afterwards in England, he studied the

mode of transmitting power that was being practised in some of the foreign cities. Feeling impressed that it would not be wise for any large amount of money to be expended without knowing exactly what was the best method of proceeding, he sent a cable, asking me to meet him in London.

I met Mr. Adams in London, in May, 1890, and found that he was more enthusiastic than ever in the scheme, but that he was impressed with the idea that as there is not enough land around Niagara to use the power proposed to be developed for the inhabitants, the operatives, and the mill sites, it would be advisable to make the market larger by transmitting the power to a greater distance. With Mr. Adams I visited some parts of Switzerland and Paris, in the latter city to see the plan or system that had been adopted by M. Popp, who, having introduced compressed air as a means of moving the works of the tower and other clocks of Paris, had begun to supply air to and work small motors. The enterprise has increased to such an extent that eventually 120,000 feet of pipe had been laid through the streets of Paris, and more than 10,000 horse-power might be generated by compressed air at his stations to be transmitted to drive engines from forty-five or fifty to 200 horse-power, and down to the smallest dental machines that are used in any establishment, and also operate the cooling chambers where provisions are kept.

In Birmingham, England, extensive works had been erected and power was being successfully transmitted by compressed air. The main thing, however, was to find out what would be the best means of transmitting the power of Niagara Falls to Buffalo, etc., and to get at a knowledge of the exact state of the art of developing water-power as well as transmitting the power. For that purpose it was proposed to interest Sir William Thomson and make him President of a Commission to consider plans to be submitted by selected engineers.

Sir William Thomson many years ago said that the time was not far distant when the city of New York and other distant cities would be lighted from the Falls of Niagara. The city of New York is a great many miles away from Niag-

ara, and I don't know that we are now very much nearer that desirable end than we were at the time he uttered the prophecy; but at all events, there is a great deal more known about transmission of power by electricity to-day than was known yesterday, or the day before. The substantial progress that has been made in this particular branch of transmission is something that is not marked by years of progression, but by daily advance with such rapidity as to astonish the world, apart from the ideal progress in the minds of enthusiastic electricians, which is always greatly in advance of actual results.

It was difficult to find men to act upon a commission with Sir William Thomson to consider the subject, because the majority of those who were noted for scientific pursuits were already retained by one or the other of the various eelctrical companies, or companies for the transmission of power, and it was not very easy to get any who were free and who could act without bias in a commission of this character.

Finally, it was decided to select Col. Th. Turrettini, the Mayor of the City of Geneva, as the representative of Switzerland, because Col. Turrettini was a noted hydraulic engineer, and it was he who had made and supervised the erection of all the improvements on the river Rhone at Geneva, whereby the individually-owned water wheels were swept away from the stream and the power of that river was transferred to all parts of the city, by pipes which convey the water from one central station, from improved pumps, worked by turbine wheels, the water being elevated to reservoirs on the hills and brought down into the town under two different pressures suited to two different classes of use that were to be served. Col. Turrettini had adopted this hydraulic method because the Swiss people were used to hydraulics. They looked upon their mountains and the streams flowing down from the glaciers as their coal mines. They have no coal, but they have water, and water that is running down hill, and water, be it ever so little, if it only runs down hill far enough in a steady stream is a source of power that may be used to drive machinery. During only a few years past,

small streams, that had previously run but a single small flax mill, have been made to drive tens of thousands of spindles by the improved methods of utilizing this water, and the Swiss people found that they had the means of developing a great deal of unused hydraulic power.

It is one thing, however, to develop power and another to get people to use it. America is in a better situation for the use of power than Switzerland, because there are more uses for the manufactures, and more market for the goods, and more reason why the manufactories should exist than in Switzerland. Col. Turrettini, however, would not repeat the hydraulic plant that is now in successful operation in Geneva. In all probability, if he was called to do the work again, electricity would be the agent that he would use for transmission, because at the great falls of Schaffhausen, and other places in Switzerlaand where the power has been transmitted by wire rope to a number of mills, they are now substituting for their much-lauded rope transmission, electrical transmission of power, and claim to be doing it in a paying way.

Near the town of Grenoble, in France, there was a paper mill that was operated by steam. It didn't pay, and it was proposed to take water-power, about five miles off in the mountains. These mountains are inaccessible in winter. During that season it is impossible for any one to pass from the paper mill to where the wheels are placed, and they can only communicate with each other by means of the telephone or telegraph. For nearly two years this paper mill has been operated by the water of a stream in the mountains that has given them the power to run their works without the slightest interruption by any of the great storms that prevail in these mountains. They say they have now become used to it, and are so well satisfied with it that they propose duplicating their machinery to rent power, which they can do profitably at the rate of about $20 per horse-power per annum. At that place they claim fifty-five per cent. efficiency by the continuous current they are using.

To co-operate with Col. Turrettini and Sir William Thomson, by the advice of many who knew him well, Prof.

Mascart, of Paris, the head of the Meteorological Bureau of France and professor in the University of France, was selected because he is known to be well-informed on the possibilities of electricity.

By great good luck, Prof. W. C. Unwin, of the Central Institute of London, Dean of the Faculty of that great school which is intended to teach the sciences to young men under the patronage of the United Guilds of the city of London, was induced to accept the position of Secretary to the Commission, so that the Commission came to be:

Sir William Thomson, President; Coleman Sellers, Professor of Mechanics of the Franklin Institute, as representing the company and the United States; Col. Th. Turrettini, Mayor of Geneva, Switzerland, to represent his country; Prof. E. Mascart, of Paris, to represent France; Prof. W. C. Unwin, Secretary.

The headquarters of the Commission, by the kindness of the Directors of the Central Institute, was established for the time in the Central Institution building in South Kensington, and in that room the many conferences were held and the correspondence conducted that was required in a matter of such great importance to the company interested, and to the scientific world at large.

At early meetings of the Commission held in London, the persons were selected whose advise was deemed of great value and these engineering firms and individuals were asked to submit plans:

(1) Of the generation of the power by turbines or other water motors.

(2) For the transmission of the power so generated to the factories on the land of the company, and then to an area within a two-mile radius from the Central Station. After that to Buffalo and Tonawanda, or to the area contained in a circle within a radius of twenty miles.

Not only were substantial prizes offered, but to all those who would submit plans and estimates in accordance with the specifications, a sum of money was to be paid that would in some degree compensate them all for the labor expended.

The plans and estimates came in on the last day of the

year 1890, but the meeting of the Commission to decide on the plans was not held until the latter part of the month of January, 1891. This meeting lasted one week and was conducted with great care and dignity, mainly in French.

Some of the estimates submitted were remarkable, illustrated by many costly drawings, finished on the highest plane of excellence and accompanied by volumes of valuable information. The whole of the plans were so duplicated that each member of the Commission became possessed of a set of the drawings, specifications and estimates, as also of the written explanations that accompanied them.

All of these schemes were based on what the company has already begun, and which I will briefly explain to you.

The Niagara River above the Falls, flows from the east to the west and at the Falls, the lower gorge into which the water is carried by the two great Falls, the American and the Horse-shoe, runs almost due north towards the west end of Lake Ontario. Between the line of the New York Central Railroad as it enters the town of Niagara, and the river bank, is a strip of land averaging sufficient width to permit the laying out of a manufacturing town as an extension of the town of Niagara, with room sufficient to permit a long canal from the river to run parallel with the railroad, to enter the river below Grass Island with a diverging mouth of sufficient width to, of itself at its lower end, give water at the Central Station to the whole amount required if need be.

Streets are being laid out above Port Dey, where the existing hydraulic canal takes its water, for the location of mill sites, while farther up the river a large area of land, in all about 1,400 acres, will be reserved for dwellings of the operatives in conjunction with other large areas not owned by the Niagara Power Company, but being worked in harmony with it.

A tunnel requiring about 490 square feet of rock excavation is being driven from above Port Dey on the land of the company under the town of Niagara to a few feet below the Upper Suspension Bridge, a total length of 6,700 feet to be extended up stream farther, as required when the mill sites

may be occupied. Only the lower end of the surface canal, as designed to feed the wheels that are to discharge into the tunnel, will be at present built, as from this point all the business will be allowed to grow upon the lines presently to be pointed out to you.

The tunnel will pass under the existing hydraulic canal that feeds the mills, which at present exist in the town of Niagara on the bank below the Falls. This canal has been in operation for about forty years, and begins at Port Dey, at the immediate head of the Upper Rapids of the American Fall; Port Dey taking its name from one who was largely interested in the enterprise and who has been noted for his connection with the manufacture of india-rubber in the United States. The canal passes through a reservation 100 feet wide, but is only 35 feet wide, and carries the water into a forebay parallel with the lower river, whence various factories are being fed. The whole amount of water that this canal will deliver is already exhausted so far as the power it is capable of yielding is concerned, with at present an operating efficiency of about 6,000 horse-power. This power may be increased to double the amount by utilizing all the available fall, but it cannot be increased beyond that without deepening or widening the existing canal.

It may be noted here, that the mills that are fed by this hydraulic canal have been conducted with profit to their owners, on account of the steadiness of the water-power and the many advantages offered by Niagara as a site for manufacturing operations, as well as the great railroad facilities that have been for a long time in existence.

The question has many times been asked, why use a tunnel for a tail-race and place the mill sites above the Falls, when a more natural plan would be a duplication of that already illustrated in the hydraulic canal feeding the existing mills? I might here give a few reasons why it cannot be done. In the first place there is no land at any reasonable price available for manufacturing purposes along the lower river. Public opinion is very much against the further extension of manufactories on the banks of a stream to the detriment of its picturesque features, and for the

preservation of the æsthetic elements of the Falls, large sums of money have already been expended to secure and perpetuate them. It was at a very great expense that the State of New York bought from the owners, the mills that were standing on Bath Island in the Upper American Rapids, and bought the land immediately adjacent to the Falls, and laid out the beautiful park which is now free to the public, and enables all who may wish, to view at their leisure the wonderful cataract. There is a strong feeling against any further erection of manufacturing establishments on that part of the river, and were such an enterprise feasible by reason of land available for the purpose, I would beg you to note that from the head of the upper rapids to the bank of the lower river there is a fall in the ground, leaving less available head at the lower chasm than is represented by the total head between the water above the upper rapids and the water in the lower river, which is about 216 feet, while at the lower gorge it is not quite 200.

Water cannot be carried by canals at nearly so rapid a rate for use in water-wheels as the tail water or waste water that runs away from them can be discharged through a tunnel of rock. For canal purposes, a velocity of not much over three feet per second is the amount that is safe to use, while in an underground tunnel the velocity may be carried, without serious detriment to the rock bed or to brick lining to as great a speed as twenty-five feet per second. Now it is this possible high speed in the tunnel, which does not occupy any space so far as buildings are concerned, but passes under the town through a right of way that has been granted for the purpose, that enables a volume of water to be discharged which if it were carried by canal on the surface of the ground, would require a canal to be perhaps 400 feet wide and from 10 to 15 feet deep, forming of itself quite a a respectable river.

The plan proposed by Mr. Evershed contemplated a number of surface canals entering the land of the company one above the other, at right angles to the river, and passing from the tunnel, which was to extend under the new town. This plan has been changed to the one canal with

lateral branches that I have mentioned. The canal construction will begin at its lower end only, that the company may decide tentatively upon what is the best line of proceeding to obtain the end they have aimed at.

In regard to the possibility of utilizing this power and doing it to the best advantage, the company can proceed at once with certainty as to what will be advisable as a beginning. Changes in modes of manufacturing and transmission are going on so rapidly, and so much information is being received, that it has been decided that a certain amount of power will be sold for local mills that shall control their own wheels and deliver water into this tunnel. This is to satisfy those people who wish to conduct their own manufacturing establishments in the old-fashioned manner.

There will be a central station for the generation, first of about 5,000 horse-power by compressed air, another one of 5,000 horse-power by electricity, with the possible extension of either one of these to the amount of 100,000 horse-power added in units of 2,500 to 5,000 horse-power to either, one by one, in whichever direction proves the most profitable and is called for by manufacturers. The company is anxious to do this work cautiously, economically and thoroughly and to avoid mistakes. With this intent the matter has been placed in the hands of a Board of Engineers, of which I am now the chairman, with Col. Turrettini as foreign consulting engineer, and Mr. John Bogart, the State Engineer of New York, as consultant with me, Mr. Clemens Herschel, the hydraulic engineer of the company, and Mr. Albert H. Porter, the grandson of the one who originally owned Niagara Falls, as the resident engineer of the company at Niagara.*

It was in 1804 that Mr. Porter's ancestor took up the land adjacent to Niagara Falls, and the Falls too, as far as his Government had control over it, from the United States Government. He was virtually the owner of the Falls and the land about it, and his family owned it down to the present time, still holding some of the land, and it was from the

* Since this address was delivered, Mr. George B. Burbank, C.E., has been made resident consulting engineer at Niagara Falls.

Porter family that the State of New York bought the land that has been made into the park, and from them bought the mills that have been erected on Bath Island in the Upper American Rapids.

Niagara offers a wonderful opportunity for a water-power of a stable character, more stable than any river that has been heretofore utilized. The difference of river level from time to time is slight, there is little more than three feet variation at the most in the river above the Falls. Whatever change takes place in the upper river to the extent of a foot, means a change of five feet in the lower river because there the channel is so much narrower and deeper that this vast width of about 6,000 feet above the Falls is forced into a narrow gorge only a few hundred feet wide. It is not known exactly how much water there is going over Niagara Falls. There have been a great many guesses and some computations that are more or less accurate, but they differ so much that doubt is expressed in regard to all of them.

The most careful examination goes to show that the amount of water taken by the Niagara Power Company, if they find people who can use 120,000 horse-power, which means a great many Lowells and Holyokes or a great many of the water-powers of New England put together, will probably affect the depth of water passing over the Falls about one inch and no more. Hardly perceptible when you think that a vessel loaded with timber has gone over the centre of the Horse-shoe Falls seemingly without touching. When you have become familiar with the stream and have learned how to realize its immensity, you will not fear loss of volume of cataract by reason of this little hole in the rock, large as it is in fact, that will be required to take away the water that has developed 120,000 horse-power.

Now 120,000 horse-power used on land serves a large amount of manufacturing industry. It seems to go farther on land than it does at sea, where the steamships that are now trying to eliminate the distance between the shores of England and America require as much as 14,000 horse-power in a single vessel. A few such ships would use up all of this

amount of power, but at sea the whole of the mighty force is expended in driving a screw at the stern of a vessel to force it across the ocean. It is the simplest and crudest form of transmitted motion applied directly to the purpose. To utilize power on the land is a more difficult problem.

Consider, if you will, what we have in Philadelphia, if you will go up towards the Reading Railroad, Broad and Pennsylvania Avenue, and look at the establishment where the wrought-iron car wheels that the Baldwin Locomotive Works have shown you to-night are made, where over 4,000 workmen are gathered in one establishment, that establishment not being on a single city block, but covering five or six city blocks and requiring all its machinery to be put in motion by steam engines with power transmitted by shafting to various parts of this scattered establishment. The 4,000 or 5,000 workmen employed in these buildings require only about 2,500 horse-power of steam to drive the machinery that is giving them employment.

Close by are the works of Wm. Sellers & Co., Incorporated, where 600 men are using about 300 horse-power of steam; in both of these cases there is about two men to each horse-power of power. But what is taking place in these establishments? In that of Wm. Sellers & Co., to which I was attached for more than thirty years, shafting has been made of the most perfect character. There the first efforts were made to manufacture shafting as yards of cloth are made, reducing it to a system that was interchangeable in its parts. What have they learned by this thirty or forty years of work? They have learned that when power is transmitted from a central engine by shafting, seldom more than fifty per cent. of the power created reaches the machines, so great is the friction of the best shafting that can be made, having the best care and with the best lubrication. For small places and short transmission this may be reduced to fifteen per cent., but when extended to a greater distance it eventually comes to fifty per cent. loss, and as the establishment becomes larger the efficiency of transmission diminishes more and more. A line of shafting two miles long could

not, it is estimated, be turned from one end; it would twist itself off before you could turn it.*

In Switzerland, they had the wire rope transmission, and carried the power with much greater efficiency than by shafting for a distance of three miles, but this is being thrown aside for electricity. I have with me papers that have now been sent from Oerlikon, in Switzerland, telling us that they estimate that power may be transmitted for fifteen miles at a cost of less than $60 per horse-power for the actual cost of machinery, etc.

There are men in England who believe that it can be done cheaper than that. I had an opportunity to see many interesting things while away, because the great places that were developing electricity were thrown open to me in a manner that was exceedingly gratifying to me. I saw the operation that is being attempted by Ferranti in London, where he believes that by going to Deptford, on the Thames River, as business men would place a gas works, so he would place his electrical station, where he can get coal cheap, get rid of ashes readily, and obtain water for his condensing engines, etc., and, though the part of London that he is to give electricity to lies at a distance of seven and one-half miles from where the main station is, he aims to transmit electricity that distance underground by concentric cables at 10,000 volts. He had several breakdowns at first, but the last account that I have is that the plant is running smoothly. Mr. Ferranti is a young man, only twenty-six years old, but he is a very venturesome mechanic. He is putting up engines of 10,000 horse-power very like such as would be used on steamships. Upon the shaft of the engine he is arranging a massive fly-wheel, which is in fact the revolving armature of his dynamo, this armature being forty-five feet in diameter. He believes in steam-power being developed in large quantities by large engines, but electricity in small units. The electrical machines that he strings around the rim of this fly-wheel he conceives can be as well placed there as strung in a line on the floor, and can be coupled up as he

* See *Kapp's Electric Transmission of Energy*, p. 233.

may require for his purpose. He has four lines of concentric cables to carry the electricity to Grosvenor Square section of London, to a station where the voltage is reduced to perhaps 2,000 for local distribution, and then by other transformers into the houses of the district. London is so vast a city that units of power for lighting that would be out of proportion in smaller towns may be none too large for such a population for the lighting of a city where over 5,000,000 inhabitants are calling for light sometimes in winter and in their dense fogs, for what with us would be day as well as during their long nights.

I understand that Ferranti has gotten through the difficulties he had to contend with through the acts of Parliament and the post-office regulations in London, because it has been found that the current in his concentric cables does not interfere with the underground telephone and telegraph wires, so London is now being lighted by this plan to a certain extent in the Grosvenor district, the part of London that I was living in.

As to the safety of this kind of transmission, I understood Lord Crawford, who was the chairman of the company, at one time to say that a man had held a chisel in his hand and allowed another man to drive that chisel by hammers through the concentric cable when 10,000 volts were being transmitted as was thought, but when in reality 15,000 volts were passing, and he suffered no damage, though he was standing with damp feet upon an iron plate upon which the naked cable lay.

I was invited to see the same experiment tried again, but I did not accept the invitation, knowing that it is perfectly safe if the chisel strikes the outer and inner conductors of copper that form the cable, the current is only short circuited, the safety fuses go off and the chisel can be so held without damage to the operator, but if a small portion of the outside copper casing be cut away and then an attempt made to cut the inner coil of copper, the operator would not know what had happened, so quickly would he fall.

In Switzerland by means of the oil transformers adopted by Mr. Brown of Oerlikon, who has experimented with

transmission by electricity at 30,000 volts, having a sparking distance of about an inch in the air, and by means of the so-called rotary alternating currents, they are about bringing to Oerlikon the power of a waterfall a number of miles from that place and driving their whole establishment by electricity and not by steam and shafting transmission.

At the time that I visited the Oerlikon works they were already taking down line shafting and placing motors in various parts of the establishment nearest to the machinery to be driven, and though they were as yet generating their electricity by means of steam engines, they considered this method of transmission much more economical than shafting, and they proposed to extend it throughout their entire works.

I went to Rome to see the plant there and that which is being constructed at Tivoli. The power will be brought from Tivoli to Porte a Pia at Rome by naked overhead wires at 5,000 volts, with the expectation of having at Porte a Pia about 4,500 volts to be lowered to 2,000 to enter the city of Rome by underground concentric cables, and then lowered by other transformers to enter the houses.

I was agreeably surprised when I went to Rome to see so perfect a plant as they have established there under the auspices of Ganz & Co., one of the firms that submitted plans to the Niagara International Commission. They use the alternating current and the three-wire system, and at present, so far as I can see, the alternating current seems to come to the fore on account of the ease with which it can be transmitted long distances, the voltage raised and lowered by means of transformers, not involving such great cost of cables as is required by the continuous current. At Rome, arc and incandescent lamps are operated conjointly by the same three wires.

Prof. George Forbes, was one of the first men of science to acknowledge the fact that the future of electricity looked very much as if the alternating current would be the most profitable one for transmission of power a long distance. I went with him to see the Mordey alternater at work in London, where they operated one of

their generators for us as a motor, giving it work to do to the extent of fifty per cent. more than its calculated capacity without its showing the least fatigue, and after half a day's work not even being warm. There was no trouble in any way with it and it illustrated the beautiful condition of being constant in its speed, no matter whether a load was taken off or put on, for when the driving power is constant and uniform in its speed, the motor driven by it and in step with it is constant, being in no way affected by change of load.

Speaking of Prof. George Forbes, so well known as a scientific electrical engineer, I was much impressed by his bold stand in favor of the alternating current, and his command of the subject as an educated engineer, in presenting his plan of utilizing the power of Niagara. Looking back to the meeting held in London and my opportunity to meet men noted in scientific engineering, some among them seem to tower mentally over others, and one can readily feel that such men are masters.

In Rome, where the experiment was first demonstrated practically of running alternating current dynamos parallel, coupled electrically only, and not by mechanical coupling, the engineer of the Roman works, Dr. Mengarini, has adopted as a unit 600 horse-power for the Roman plant where it is driven by steam made from the coke of the gas works, but at Tivoli the units of power will be 350 horse-power each.

In Rome, where the Cæsars built their great circus, and on the very stones placed by Cæsar, stands the foundation of the engines that now furnish light by gas and electricity to the city of Rome. The gas company of Rome concluded to create electricity by steam only as far as the coke as a by-product of their gas works would permit them to do it, but it is for additional supply they go fifteen miles away to Tivoli to take advantage of the water-power at that place and bring thence to Rome electricity at a high voltage. The beautiful old villas that stood along the olive covered heights of Tivoli have been faced by a grand aqueduct that brings the water collected from streams to one huge build-

ing, where the first fall of the water is 160 feet to the first set of wheels, where in one room six wheels will give motion to the six dynamos, with three other dynamos to give the constant current for the magnetization of the six main dynamos, and after that when they wish to extend their plant, they can drop 160 feet more to other wheels and even then they will not be at the bottom of this great building.

The work of the Cataract Construction Company at Niagara is now being pushed as rapidly as it can be, and it is gratifying to know that people are already looking forward to Niagara as a home. There has been leased already to one single firm for the purpose of paper mills and pulp works, 3,000 horse-power, and they will begin the erection of their works at once.

You may wonder why compressed air is thought of at all for transmission, as you have known in America that it has been thought to be a very wasteful manner of transmitting power, but the recent improvements that have been made in compressors have very much changed the condition of that mode of transmission and the fact that so much gain is possible by reheating the air indicates a cheap power which can be transmitted long distances, with economy, dispensing with long lines of shafting.

I myself think that electricity is the most perfect and economical method of transmitting power, but people are not ready to set aside their steam engines and substitute electric motors for them at once. They will take air that can be given to them in place of steam when they find that a handful of coal will very much increase the power of that air at their works and enable air motors to be used close to the machines to be driven.

I was in one establishment at Birminghan where there were many houses united together that had been added one after another to form an establishment for making bedsteads. Formerly power was transmitted to each by shafting from a central engine—a very wasteful process—but when compressed air was put into Birmingham by Mr. Sturgeon and Prof. Lupton, this bedstead factory took this compressed air from the station, passed it through a coil

boiler over an ordinary fire made of coke that is no larger than would be required to heat an ordinary dwelling house, the fire tended by a boy. The air passing through this boiler is carried to engines and these engines run without any attention whatever. The engines are warm—the air is exhausted at a temperature a little above that of the outside air, not down to the freezing point, the pressure of air is at most only sixty or seventy pounds and they have something to work with that is like the steam used formerly to drive steam engines. Cupolas are driven by a jet of high-pressure air in a jet blast; so are blacksmith forges in the same way, and so on all the different parts of the establishment; everything is done by compressed air and with absolute satisfaction.

In Paris it became popular at once because it is difficult to introduce steam into that city. Coal is very costly, the municipal regulations are against the use of steam; they are afraid of it. They are not afraid of compressed air. Having laid the pipes down for one purpose (that of operating clocks) it was an easy step to introduce it for other purposes. The establishment at which Mr. Popp is the head has more to do than at Birmingham. He is doing some part of the city lighting by electricity. Why doesn't he transmit the power by electricity? All I can say is that he don't do it. From his main station he transmits the compressed air to engines that drive the dynamos to light other parts of Paris. Mr. Popp sent me a very interesting communication a few days ago, saying that the government of Paris was very much concerned about stocking the city of Paris in case of another siege, and a large sum of money was voted by the government to have experiments tried in the various methods of keeping provisions in cooling chambers. Mr. Popp told them it wasn't worth while to be uneasy about that, and he invited the Secretary of War and others to the stations I had visited in Paris, where there may be about 10,000 horse-power generating compressed air. He said that by driving one-half of this machinery itself by compressed air instead of by steam, and building temporarily near this station cooling chambers to contain

the provision, that at once cold air from the exhaust could be thrown into them to lower the temperature below the freezing point, and give them sufficient cooling capacity to carry the provisions for at least a six-months' siege of Paris, if not longer, without any great cost. The very machinery that had been used to give power in peace, could in a state of siege when power wouldn't be wanted, at once be turned into another use, that of furnishing the means of keeping the provisions that were required to feed the population locked in by an invading army.

This use of compressed air for cooling purposes is an important item in favor of its use in large cities, and it is being considered by some of the other great cities of Europe. Berlin and other cities are now perfecting their organization for the erection of compressed-air establishments to supply power as it is supplied by water in London, by compressed air in Paris and Birmingham, and in a slight degree by steam in New York, but in very few places by electricity.

Compressed air has been quite successfully used on some of the tramways. One tramway that I visited at Chester, England, is an example of such a system of low-pressure compressed air. It is necessary to carry only fifty cubic feet of compressed air in each tram-car, as they can recharge without stopping. Whenever they want to take up a charge of compressed air they drop a plow blade which lifts up a cover plate with grooves on its lower side, the groove forms a guide connecting the car attachment with the device for letting in the compressed air. I have seen the tram-cars so arranged running at full speed, open the plate, take the charge, and shut the plate without any interruption. In Philadelphia the roads could be supplied with that system admirably, because it does not follow that the power must be transmitted over every foot of the line as it is by the trolley system of electricity, but each car carries the power from station to station compressed within its reservoirs and the car is not a helpless dead machine when off the track, but carries its power with it.

The development of compressed air at Niagara, you can

understand, merits consideration when 50,000 horse-power, we are told on good authority, can be carried twenty miles distant through two pipes, each 26 inches in diameter, with a certainty that by increasing the pressure for the time being, one pipe alone might carry the entire amount while the other one would be under repair, so it is not so very costly, after all, to carry power by means of it, and people can use what they are accustomed to, an elastic gas similar to steam so that large and small steam engines now in existence can be operated as if by steam. This is what is inducing the company to be prepared to develop its work on the three lines: one of compressed air, one of electricity, and the other of developing it on the ground by separate wheels, but I would like all of you to think of this subject as mechanics, and to think of what is now being done in the present method of transmission, and how rapidly people's eyes are being opened to the necessity of some other mode of transmitting power. Electrical motors are now used to work 100-ton travelling cranes and in comparison with square shaft driving are considered more economical. Electricity, too, is used to drive swing cranes and drilling machines. It lends itself to division in a manner that is wonderful in the extreme and permits better results than anything that can be conceived of, the only doubt is that the progress of invention is going on so rapidly that we are almost at a loss to know what particular line should be pursued in preference to others, and therefore the Cataract Construction Company proposes to proceed tentatively.

Before I quit the subject of compressed air, I will tell you of a man in England, Mr. J. Pearsall, who was one of those who presented plans to the Commission, and who says that the best way to generate the power by compressed air is to do it by a hydraulic ram. Pearsall is no visionary. He has already accomplished the result on a small scale. There is running in Pennsylvania one of his machines, and he has adopted the principle of the hydraulic ram with which you are all familiar and in place of the valve closed with a slam by the current he has introduced a set of valves driven by a separate power, thus doing away with the weak point of the

ram system and made it perfectly and entirely feasible to compress air by the water, not by the weight of the fluid columns only, but by the impact of the water. Having obtained power by velocity, by properly operated valves he cushions the stream on the air, compressing it and driving it into the distributing mains.

He has shown on a small scale that this can be done much more cheaply than by creating the power by water wheels and compressing the air by costly compressive machinery, so that this may be looked at as one of the modes that will render the use of compressed air cheaper than electricity.

I have given you a brief outline of what is being done at Niagara, and I would like to tell you of many more interesting things seen in England, but I must call your attention to one difference of methods that prevails between engineers in Europe and in this country.

I found, go where I would on the Continent of Europe and in England, that engineers were using the ordinary carpenter's slide rule, usually the kind called the Gravet slide-rule, for doing all their calculating, while here few know anything about it at all. I began to inquire into this while in London, and found that they have some remarkable instruments for this purpose that are convenient to carry and useful in every way. With these instruments calculations are made without pen or pencil far more readily than you could possibly do them by the old-fashioned method. A celebrated engineer said that everybody should learn to calculate by the rules of arithmetic, but as soon as they got hold of a machine to do the work for them, they had better forget the rules learned at school. It would be well for young engineers to become accustomed to using these instruments, for it is easier to learn to use them while young than later in life.

I have in my pocket (producing the Boucher's calculator) a little instrument that looks like a watch, a calculating machine where the scales of the slide-rule are in a circle; one side of the instrument gives square roots and the other cubes, the logarithms and sines, etc. If now, you want to know the power of a certain engine, knowing its speed,

mean effective pressure and dimensions, this little instrument will resolve the simple equation of

$$\frac{\text{area of piston} \times \text{mean pressure} \times \text{feet per minute}}{33{,}000}$$

by successive setting of the dial or pointer with an answer at the fixed index. It is done at once without any calculation, without any trouble, and without the possibility of a mistake.

There have been many forms of these instruments devised. In one the scale of logarithms is wound around a cylinder; such is the Fuller spiral calculator, representing an ordinary straight slide-rule eighty-two feet long and capable of being read to five or six figures.

If it has been worth while for me, at my time of life, to learn the use of these instruments, it is surely worth the time of you younger men, for I can assure you that things like this are not picked up as quickly after you have passed fifty as in earlier life, and it is well worth the effort required to master them.

I hope what I have said has been of interest to you, and thank you for your earnest attention.

[At the conclusion of his remarks, the thanks of the meeting were unanimously voted to the speaker.]

NEW ALLOYS AND THEIR ENGINEERING APPLICATIONS.

BY F. LYNWOOD GARRISON.

[*A lecture delivered before the Franklin Institute, January 30, 1890, and February 6, 1891.*]

[*Continued from vol. cxxxi, p. 460.*]

Dr. Dudley writes, "We tested the test bar and found 78,500 tensile strength with fifteen per cent. elongation in two inches, and four and one-half per cent. in eight inches. This high tensile strength can only be obtained when the metal is manipulated. Such high results could hardly be expected with the cast metal.

The following analysis of Tobin bronze,* made for me by Mr. James S. de Benneville, agrees very closely with the rolled test bar analyzed by Dr. Dudley:

Copper,	61·203
Zinc,	37·440
Tin,	0·906
Iron,	0·180
Lead,	0·359
	100·088

The alloy is, therefore, practically a brass. It is a well-known fact (as I have already observed in the case of sterro or delta metal) that the presence of a small amount of iron in a copper-zinc alloy has a tendency to increase its strength and ductility, while the lead present tends to make it softer and more fusible.

The Ansonia Brass and Copper Company, who are, I understand, the sole manufacturers of Tobin bronze, claim to obtain 79,600 pounds per square inch tensile strength,† an elastic limit of 54,257 pounds per square inch,‡ and from

* Patented by John A. Tobin, Engineer Corps, U.S.N.

† Tests made by Fairbanks.

‡ Tests made by Prof. J. E. Denton.

twelve to seventeen per cent. elongation with best rolled one-inch bars.

Tobin bronze, according to the inventor's claims, can be forged and stamped at a red heat as readily as steel. Bolts and nuts can be forged from it by hand or by machinery, when cold drawn. Its increased density and high elastic limit, and the facility with which it can be upset, while hot, make it well adapted for special purposes. In forging Tobin bronze it is stated* that particular care must be taken to work it only at a cherry-red heat, and that it should not be worked at a black heat.

Tobin Bronze.—This alloy is practically a sterro or delta metal with the addition of a small amount of lead, which tends to render copper softer and more ductile.

The following analyses of Tobin bronze was sent me by courtesy of Dr. Chas. B. Dudley, of Altoona, Pa.:†

	Pig Metal. Per Cent.	*Test Bar (Rolled). Per Cent.*
Copper,	59·00	61·20
Zinc,	38·40	37·14
Tin,	2·16	0·90
Iron,	0·11	0·18
Lead,	0·31	0·35

Copper Alloys containing Phosphorus.—Under this head we have three alloys, which have become of any prominence for engineering purposes, viz: phosphor bronze, deoxidized bronze and the so-called Eureka tempered copper.

Phosphor Bronze.—In the year 1868, Messrs. Montefiore & Künzel, of Liège, Belgium, found, by adding small proportions of phosphorus or "phosphoret of tin or copper" to copper, the oxides of that metal, nearly always present as an impurity, were deoxidized to a greater or less extent and the copper much improved in strength and ductility, the grain of the fracture became firm, the color brighter, and a greater fluidity attained.‡

Combinations of phosphorus with copper, and with tin,

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* *Ansonia Brass and Copper Company Catalogue*, p. 6.

† Private communication, January 23, 1891.

‡ *Journal of the Society of Arts*, May 4, 1877, pp. 551, 552.

have long been known to chemists, but Dr. Künzel was the first to employ the same for the purposes I have stated.

Perhaps about the best method of making phosphor bronze is to line the crucible with a mixture of eighteen parts bone-ash, fourteen parts sand, and four parts charcoal; the whole ground up with gum-water and the inner surface of the crucible spread with it. Granulated copper then being introduced, covered with a layer of the mixture and subjected to fusion.

At a temperature sufficient to melt the copper, the silica decomposes the bone-ash [$Ca_3(PO_4)_2$], the base of which (calcium) is removed, thus freeing the phosphorus, which reacts on the cuprous oxide in the fused copper, deoxidizing and purifying it. The products of the reaction rise to the surface, form a slag which can be tapped off.

According to Kirkaldy, phosphor bronze produced the following results by physical tests.*

	Elastic Limits. Pounds per Square Inch.	*Tensile Strength. Pounds per Square Inch.*	*Elongation. Per Cent.*
Cast, ...	23,800	52,625	8·40
Cast, ...	24,700	46,100	1·50
Cast, ...	16,100	44,448	33·40

Drawn Metal (*Phosphor Bronze*).

Tensile Strength.		Twists in 5 Inches.		Elongation. Per Cent.
Wire as Drawn. Pounds per Square Inch.	Annealed. Pounds per Square Inch.	Wire as Drawn.	Annealed.	
102,759	49,350	6·7	89	37·5
120,957	47,787	22·3	52	34·1
120,950	53,381	13·0	124	42·4
139,141	54,111	17·3	53	44·9
159,515	58,853	13·3	66	46·6
151,119	64,569	15·8	60	42·8

Samples of No. 2 alloy supplied by the Phosphor Bronze Company (London), and recommended for propellers, when tested by Kirkaldy, gave ultimate tensile strength

* *Journal of the Society of Arts*, May 4, 1877, p. 552.

of 35,392 pounds per square inch, with seventeen and one-half per cent. elongation.*

In some of Dr. Chas. B. Dudley's recent investigations on the wearing properties of metals, it was found that phosphor-bronze bearing metal of the average composition 79·70 per cent. copper, ten per cent. tin, 9·50 per cent. lead, and about 0·80 per cent. phosphorus, gave the following results :†

COPPER-TIN *versus* PHOSPHOR BRONZE.

	Composition Copper-tin. Per Cent.	*Composition Phosphor Bronze. Per Cent.*
Copper,	87·50	79·70
Tin,	12·50	10·00
Lead,	none	9·50
Phosphorus,	none	0·80

Wear.—First experiment, copper-tin bronze wore forty-eight per cent. faster than phosphor bronze; second experiment, copper-tin bronze wore fifty-three per cent. faster than phosphor bronze; third experiment, copper-tin bronze wore forty-seven per cent. faster than phosphor bronze.

ARSENIC BRONZE *versus* PHOSPHOR BRONZE—FIRST EXPERIMENT.

	Composition Arsenic Bronze. Per Cent.	*Composition Phosphor Bronze. Per Cent.*
Copper,	89·20	79·70
Tin,	10·00	10·00
Lead,	none	9·50
Phosphorus,	none	0·80
Arsenic,	0·80	none

Wear.—Arsenic bronze wore forty-two per cent. faster than phosphor bronze.

ARSENIC BRONZE *versus* PHOSPHOR BRONZE—SECOND EXPERIMENT.

	Composition Arsenic Bronze. Per Cent.	*Composition Phosphor Bronze Per Cent.*
Copper,	89·20	79·70
Tin,	10 00	10·00
Lead,	7·00	9·50
Phosphorus,	none	0·80
Arsenic,	0·80	none

Wear.—Arsenic bronze wore fifteen per cent. faster than phosphor bronze.

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* *Trans. of the Inst. of Naval Architects*, 1888, p. 370.

† *Journal of the Iron and Steel Institute*, No. 11, 1890, pp. 216, 263.

ARSENIC BRONZE *versus* PHOSPHOR BRONZE—THIRD EXPERIMENT.

	Composition Arsenic Bronze. Per Cent.	*Composition Phosphor Bronze. Per Cent.*
Copper,	79·70	79·70
Tin,	10·00	10·00
Lead,	9·50	9·50
Phosphorus,	none	0·80
Arsenic,	0·80	none

Wear.—Arsenic bronze wore one per cent. faster than phosphor bronze.

DAMASCUS BRONZE *versus* PHOSPHOR BRONZE.

	Composition Damascus Bronze. Per Cent.	*Composition Phosphor Bronze Per Cent.*
Copper,	77·00	79·70
Tin,	10·50	10·00
Lead,	12·50	9·50
Phosphorus,	none	0·80

Wear.—First experiment, damascus bronze wore eight per cent. slower than phosphor bronze; second experiment, damascus bronze wore 7·30 per cent. slower than phosphor bronze.

	Composition Alloy "B." Per Cent.	*Composition Phosphor Bronze Per Cent.*
Copper,	77·00	79·70
Tin,	8·00	10·00
Lead,	15·00	9·50
Phosphorus,	none	0·80

If we interpret the above results correctly, they indicate: First, that copper tin wears nearly fifty per cent. faster than standard phosphor bronze; second, that arsenic bronze, containing no lead wears about forty-two per cent. faster than phosphor bronze; third, that arsenic bronze containing seven per cent. of lead wears less rapidly, the exact figure being fifteen per cent. faster than phosphor bronze; fourth, that arsenic bronze containing the same amount of lead as phosphor bronze, wears but slightly faster, the figure being one per cent.; fifth, that damascus bronze containing as high as 12·50 per cent. of lead wears from seven to eight per cent. slower than phosphor bronze; and, sixth, that the experimental alloy "B," containing less tin and more lead than any of the other alloys experimented with (the figures being eight per cent. of tin and fifteen per cent. of lead, instead of ten per cent. of tin, and 9·50

per cent. of lead, as is characteristic of phosphor bronze) wears 13·50 per cent. slower than phosphor bronze.

Another, and perhaps the most general, method of making phosphor bronze, is by the single addition of *phosphor tin.* Phosphor tin is made by heating three parts of anhydrous phosphoric acid with one part carbon and six of tin. The resulting alloy has a silvery white crystalline appearance, which dissolves in hydrochloric acid with the generation of sulphuretted hydrogen. According to Pelletier, this alloy appears to possess the composition of Sn_3P_2; it melts at 370° C.*

In Brannt's metallic alloys it is stated "that, according to the purpose for which the bronze is to be used, from 0·25 to 2·5 per cent. of phosphorus is added."† He gives the following analyses of different kinds of phosphor bronze:

	I.	*II.*	*III.*
Copper,	90·34	90·86	94·71
Tin,	8·90	8·56	4·39
Phosphorus,	0·76	0·196	0·053

It will be observed that the amount of the element phosphorus present—which is supposed to give the alloy its distinction—is extremely small. This, however, is only what might be expected if the supposed *rôle* the phosphorus plays in the manufacture of the alloy is the correct one.

It will be noted that the analysis by Dr. Dudley, which I have quoted, indicates the presence of 9·5 per cent. lead. Dr. Dudley states that this analysis is an average one, and will not vary more than one or two per cent. in the amount of the constituents from hundreds of thousands of pounds which have been received and used by the Pennsylvania Railroad Company.‡

Besides, as a bearing metal, phosphor bronze is useful for a large number of purposes, such as pump cylinders, hydraulic presses, piston rings, eccentric rings, etc., also for propeller blades, bells, wire, screws, gun-powder machinery,

* See *Dingler's Journal*, 225, p. 514; and 221, p. 188. *Zeitschrift für das Berg-, Hütten- und Salinenwesen im Preussischen, Staate*, 1876, s. 6.

† Page 208.

‡ Private communication

tools, etc. Blast furnaces are sometimes provided with phosphor-bronze tuyeres, which which are said to give most satisfactory results.

Deoxidized Bronze.—This alloy is manufactured by the Deoxidized Metal Company, of Bridgeport, Conn. It resembles phosphor bronze somewhat in composition and also delta metal, in containing zinc and iron. The following analysis gives its average composition:*

Copper,	82·67
Tin,	12·40
Zinc,	3·23
Lead,	2·14
Iron,	0·10
Silver,	0·07
Phosphorus,	0·005
	100·615

It seems probable some deoxidizing flux containing phosphorus, similar to that used in the manufacture of phosphor bronze, is made use of in the manufacture of this alloy. Deoxidized bronze is largely used for wood-pulp digesters, as it is found to resist the action of sodium hyposulphite and sulphurous acid remarkably well. The above-mentioned company have been quite successful in making these digesters, which are usually cast in annular sections (weighing about 4,000 pounds each) and bolted together through their flanges. The company claim this alloy to be superior to any other bronze for blast furnace tuyeres. This claim, however, I believe to be unsubstantiated, as I cannot see that it is any better for this purpose than several other similar alloys.

Deoxidized bronze wire has a tensile strength in the neighborhood of 150,000 pounds per square inch. The deoxidized copper wire made by this company, has a tensile strength of 70,000 pounds per square inch; and the deoxidized copper sheets, a tensile strength of from 30,000 to 50,000 pounds per square inch.

Eureka Tempered Copper.—The application of the term

* Analyses were made by Mr. Jas. S. de Benneville in Dr. F. A. Genth's laboratory.

tempered, as generally understood, to this product, is a misnomer. The material is not in any sense tempered or unusually hardened, it is practically pure copper, which by some treatment* has been successfully cast into small and rather difficult shapes.†

The following analysis by Dr. F. A. Genth, of Philadelphia, of the Lake Superior pig copper from which the castings were made, and the tested castings themselves, show the composition of the castings to have been but very slightly affected by the so-called hardening and tempering treatment.‡

	Pig Copper. Per Cent.
Silver,	0·096
Copper,	99 890
Tin,	trace
Lead,	trace
Iron,	0·056
	100·042

	(1) *Not Tempered. Per Cent.*	(2) *Tempered. Per Cent.*
Silver,	0·026	0·025
Copper,	99·930	99·981
Tin,	none	none
Zinc,	none	none
Iron,	0·082	0·088
Aluminum,	none	none
Arsenic,	0·046	0·042
Phosphorus,	0·017	0·018
	100·101	100·154

It would seem from the analysis that during the treatment arsenic and phosphorus were used in some way, probably as a deoxidizing flux, the chemical reactions taking place being similar to those which take place in the manufacturing of all deoxidized alloys.

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* The process is not patented and consequently we can only guess at what it may be.

† The use of the word *difficult* here is relative, as copper castings are rather unusual and are generally supposed to be difficult to make.

‡ *Journal of the Franklin Institute*, December, 1890, p. 418.

The treatment does not appear to affect the physical properties to any extent, the "untempered" cast material of a section ·6493 square inch gave elastic limit 10,080 pounds per square inch, tensile strength 24,410 pounds per square inch, elongation 22·5 per cent.; "tempered" cast material, elastic limit 11,460, tensile strength 25,800, elongation 18·0 per cent.

When rolled on section of ·465 square inch, elastic limit 27,000 pounds per square inch, tensile strength 61,290 pounds per square inch, elongation 4·3 per cent. in six inches.

Compression test on section ·935 x ·938 x 1 inch high was, strain 54,040 pounds per square inch, limit of elasticity 14,820 pounds per square inch, compression 0·28 inches or twenty-eight per cent. On section ·935 x ·939 x 1 inch high, strain 51,600 pounds per square inch, limit of elasticity 15,940 pounds per square inch, compression 0·276 inches, or 27·9 per cent.*

Compression test on a section 1 x 1 x 1 inch of Lake Superior pig copper (untreated or "untempered") was, strain 50,000 pounds per square inch, compression 0·21 inches or twenty-one per cent.

It would seem from this that the untreated pig copper actually withstood the compression strain slightly better than the treated material.

This material (so-called "tempered copper"), however, seems to be particularly good for the following purposes: For bearings on coal-mining machinery it lasts much longer than any other metal before used; that it outlasts from three to four times the old style of commutator copper bars or brushes; very satisfactory for brasses on engine rods; bearings on dynamos run very cool and require but little lubrication; gives entire satisfaction on the bearings of threshing engines; in wrist-pan boxes and in cross-head; as a step in gauge lathe, between end of spindle and set-screw, is superior to hardened steel, brass, rawhide or wood, all of which were previously tried; very uniform in hardness and

* *Journal of the Franklin Institute*, December, 1890, p. 420.

remarkably free from blow-holes; gave good results as a driving pinion in gear work; stood up well as armature bearing in street-car motors (a trying test), in small bearings, where the brass bearings would not last over sixty days the tempered copper has been nearly in a year, and is apparently in as good a condition as when first put in.*

Silicon Bronze.—This alloy appears to have been invented about the year 1881, by M. Weiller, of Angouleme.† In experimenting with phosphor bronze wire for telegraphic and telephonic use he found its conductivity was insufficient for telegraphic purposes, so he devised the alloy now called silicon bronze.

The silicon-copper compound, from which the silicon bronze is produced, is made by melting, in a graphite crucible, certain amount of copper with a mixture of fluor-silicate of potassium, produced glass, chloride of soda, carbonate of soda and choride of calcium. It is claimed the silicon and sodium in this mixture absorb all the oxides present in the mass.‡

The action of the silicon on the copper is similar to that of phosphorus. It acts as deoxidizer and, the silica formed being an acid, is a valuable flux for any metallic oxides remaining unreduced. Wire made from this alloy is said to have the same resistance to rupture as phosphor-bronze wire, but with a much higher degree of electric conductivity. According to Preece, phosphorus has a most injurious influence on the electrical conductivity of bronze, and that silicon bronze is far superior.§ It also seems that, although wires made from this alloy are very much lighter than ordinary wires, they are of equal strength.

According to E. Van der Ven,|| phosphor bronze has about thirty per cent., silicon bronze seventy per cent., and steel ten and one-half per cent. of the electrical conductivity of copper.

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* *Journal of the Franklin Institute*, December, 1890, p. 422.

† *Hiorn's Mixed Metals*, p. 199.

‡ See British Patent, 1485, 1877.

§ *Hiorn's Mixed Metals*, p. 199.

|| *Musée Teyler and Electrotch. Zeitsch.*, 1883.

The manufacture of silicon bronze has greatly improved since its introduction; the latest kinds, while perhaps somewhat less in conductivity, have a greater strength, which allows the wire to be more tightly stretched with greater spans. Such wire appears to be particularly efficient when subjected to strains caused by snow and ice accumulations.

IRON ALLOYS.

When metallic iron is combined or, I might say, alloyed with various proportions of the element carbon, we have the ordinary varieties of iron and steel, the purest being wrought iron, containing about ·015 per cent. carbon, then steel with from 0·15 to 1·5 per cent. and cast iron with upwards of 1·5 per cent. There are, of course, numerous intermediate grades whose properties, in a general way, may be said to depend upon the varying proportions of carbon present. There are other elements nearly always present, which to a greater or less degree affect the properties of the metal.

The relations of the carbon, more particularly, and also the other elements present in the iron, bears upon the properties, mode of treatment, etc., of the metal belongs more particularly to the metallurgy of iron proper. It is my intention in this lecture to confine myself to a class of compounds (alloys) which have of late attracted much attention and may be considered essentially new. I refer to the combinations of iron with such elements as aluminum, chromium, copper, manganese, nickel, silicon and tungsten; these alloys are termed steels with a prefix of the name of the predominating and particular element present.

These alloys constitute about the most difficult class with which we have to deal. The influence of some of the elements above-mentioned is exceeding subtle in many cases, and while numerous experiments have been made with most of these steels few or none have been attempted with their combinations, as for instance a steel composed of a mixture of nickel steel and copper steel.

One thing must not be overlooked in considering alloys of steel, that whereas frequently admirable results are

obtained, in some respects the material is practically worthless on account of its unworkability in the ordinary operations of the machine shop, such, for instance, as some of the grades of manganese steel.

One of the most serious disadvantages, connected with the use of mild steel for ship-building purposes, is its greater liability to corrode in salt water than iron. This is due to the usually greater purity of mild steel. In several of the new steel alloys, more particularly nickel steel, this defect is overcome, as in them we have a particularly homogeneous material of even greater strength than mild steel and much less corrodible by the action of salt water.

Some of these alloys seem to be particularly well adapted for rivets; the importance of this fact cannot be over-estimated when we consider that the limit of strength of steel suited for ship-building, boilers and other riveted structures is not so much determined by the quality of the steel that might be used, as by the quality of the rivet steel used in combining plates of high tensile strength. The Landone Steel Company some years ago found, by the results of many experiments, that the limit of strength of steel best suited for ship-building was not determined so much by the quality of the steel plates as by the quality of the steel rivets used.

I should mention that none of the tables in the following text are original, having been derived largely from Howe's work on steel and from other sources, such as Hadfield's papers, etc.

[*To be continued.*]

PROCEEDINGS

OF THE

CHEMICAL SECTION

OF THE

FRANKLIN INSTITUTE.

[*Proceedings of the stated meeting, held Tuesday, June 16, 1891.*]

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, June 16, 1891

Dr. W. H. WAHL, President, in the chair.

Ten members present.

ominations:

Dr. W. P. Mason, Troy, N. Y.

Oliver Hough, 325 South Sixteenth Street.

Owing to the absence of the election committee, a motion was made by Mr. Bower to suspend the rules, so as to permit of the election of the above gentlemen by the Section. Carried.

Dr. Mason and Mr. Hough were then elected.

Mr. Garrison's paper was postponed until further notice.

Dr. Koenig read an interesting paper on "A Remarkable Boiler Scale from Galveston, Tex." Referred for publication.

Mr. Ives gave some illustrations of the results he has obtained in color photography.

Prof. Trimble presented a paper on "The Tannin of the Chestnut Wood." Referred for publication.

Dr. Wahl exhibited a new incandescent gas lamp, similar in structure to the Welsbach incandescent lamp, but said to possess more lasting properties.

Adjourned. LEE K. FRANKEL, *Secretary pro tem.*

On the PERCENTAGE of IODINE absorbed by LARD OIL by the HÜBL METHOD.

By Reuben Haines.

[*Read at the stated meeting of the Section, held March 17, 1891.*]

The examination of lard oil for adulterations is of importance not only from an economical point of view, but also because admixture with a partially drying oil, such as cotton-seed, renders it unsuitable for lubrication and deteriorates its quality for oiling yarns in textile industries. Adulteration with unsaponifiable substances and hydrocarbon oils or waxes would seriously interfere with its use in textile manufactures. It also has been said, that admixture with cotton-seed increases risk of fire from spontaneous combustion in oily waste.

Lard oil does not appear to be of so extensive commercial importance in Europe as it is in this country, where in addition to its use as a lubricant and in textile manufacture, it is still extensively used as an illuminating oil by the United States Lighthouse Board.

Hence, while many other fixed oils, both animal and vegetable, have been investigated in Europe with more or less completeness, one finds in foreign scientific journals few references to chemical examination of lard oil, although lard itself is frequently mentioned. The writer, therefore, thought it worth while to collect together the few scattered references that exist in regard especially to the iodine absorption percentage of lard oil by Hübl's method, and to present the results of a number of examinations made by himself several years ago which have never appeared in print.

Alfred H. Allen (*Analyst*, **13**, 164) found the percentage of iodine absorbed to be seventy-four per cent. in a sample of oil pressed out in his laboratory from lard known to be entirely pure.

J. Campbell Brown stated in a discussion that the percentage iodine absorbed was from seventy-five to eighty per cent. (*Analyst*, **13**, 173.)

Rowland Williams (*Analyst*, **13**, 164) found the percentage to be seventy-three per cent.

T. S. Gladding found it to be 74·60 per cent. (*Analyst*, **14**, 32.)

Thomson and Ballantyne (*Jour. Soc. Chem. Industry*, **9**, 590) found 76·2 per cent. for prime lard oil. On the other hand, Mr. Allen found that an oil *believed* to be pure, which had been kept on hand for several years, absorbed only forty-one per cent. iodine; and he quotes also the result obtained by W. Moeller, of New York, who found in one sample only 47·2 per cent. absorption of iodine. (*Analyst*, **13**, 164).

The figures obtained in my own analyses agree approximately with Mr. Allen's result for pure lard oil pressed out in his laboratory, and with that of Mr. Gladding.

It is difficult to believe that the oils for which Mr. Allen and Mr. Moeller obtained such very low numbers were not adulterated oils and therefore not representative. As lard is composed chiefly of olein and stearine and as pure oleic acid absorbs eighty-five to eighty-six per cent. iodine while pure stearic acid absorbs no iodine at all, commercial stearine less than thirty per cent., and pure lard ranges from fifty-one to sixty-five per cent. with an average for mixed commercial lard of sixty to sixty-two per cent., it is reasonable to expect that lard oil, which is composed chiefly of the olein pressed out of the lard and more or less perfectly freed from the lard stearine, should have a higher absorption number than the whole unpressed lard, and the correct figure would probably be somewhere nearly midway between the figures for lard and for pure olein, or oleic acid. This seems to be really the case in the majority of instances at least. The amount of stearine left in the oil depends upon the temperature at which the pressing of the lard is conducted. I found by experiment that the oil obtained would not begin to chill or congeal until it had reached a temperature several degrees below that at which

it had been pressed out. Thus an oil pressed at 50° F. did not begin to chill or become cloudy until the temperature was below 45° F.

As the percentage of iodine absorbed by cotton-seed oil ranges from 105 to 115 per cent. with an average of 108 to 109 per cent., this average being about the figures usually found; and if we assume, as is probably true, that the correct number for prime lard oil is seventy-two to seventy-four per cent., we have a difference of about thirty-five per cent. between the iodine absorption capacities of lard oil and cotton-seed oil. This affords a sufficient range for calculating the percentage of adulterant used. Even assuming these figures as tolerably constant, I have found it difficult to obtain constant and reliable results showing less than five per cent. of cotton-seed in lard oil in experiments upon known mixtures of these oils, partly on account of the slightest variation of temperature in the laboratory or drafts of cold air from a window seriously affecting the correct reading of the column of iodine solution in the burette which is a nearly saturated solution of iodine and mercuric chloride in ninety-five per cent. alcohol. A difference of 0·1 cc. will cause a variation of nearly 0·5 per cent. of iodine absorbed by the oil as the method is usually conducted. It is absolutely necessary to have the burette protected from drafts of air and to have a delicate and accurate thermometer hung in close proximity to the burette during the whole time of the test or series of tests made in the course of the day, and frequently to observe whether any alteration of temperature has occurred. It is also necessary to use only chloroform of the highest grade of purity for solution of the oil in the flask. I now use only that grade which is sold for purposes of inhalation for medical purposes. It is also now believed that for most oils the time for absorption allowed by Hübl in his original paper is not sufficient, and that for drying, semi-drying and fish oils, the time should be extended to six hours at least, and even eight hours appears to be still better, but that it should not in any case exceed twenty-four hours. I diluted the liquid in the flask (after addition of

potassium iodide solution), with 100 cc. of water instead of 150 cc. as recommended by Hübl, as otherwise the one-quarter litre flasks used became inconveniently full for the proper manipulation if a large excess of iodine remained after the absorption. In the later tests I preferred to leave a large excess of unabsorbed iodine, and this is now considered to be necessary by those who have used this process. When this excess equals the percentage absorbed an increase of the quantity of potassium iodide is necessary up to thirty cc. of the ten per cent. solution instead of ten to fifteen cc. recommended by Hübl. Exactly the same measured quantities of both chloroform and of the potassium iodide solution should be used in the oil tests and in the blank titration tests of the alcoholic iodine solution. The hyposulphite solution should not be kept on hand very long but should be made up fresh every few weeks at longest. The alcoholic iodine solution, when freshly prepared, should stand forty-eight hours before being used in analysis, and only very pure ninety-five per cent. alcohol should be used for preparing it. The flasks used should have glass stoppers accurately fitting, and should be kept at a uniform temperature during the whole experiment. The burettes should be corked at the top when not actually running out solution, or, for the iodine solution at least, it is far better to use the new form of burette, glass stoppered at the top, with a small hole for admission of air, which is closed when not in actual use. The amount of lard oil weighed off for each test was from 0·30 to 0·40 gram, dropped into the same one-quarter litre flask to be used in titrating the oil. Usually, about 0·35 gram was taken, as this seemed to be most convenient.

On comparing the iodine absorption percentages obtained for different oils, it will at once appear that this method alone by no means assures us of the fact that the adulterant is really cotton-seed oil, since a number of other oils, such as rape-seed, sesame and peanut or ground-nut oil have nearly the same iodine absorption numbers as cotton-seed. But the applications of other tests as may seem desirable, such as Bechi's test with an acid alcoholic solution of silver nitrate (omitting the amyl alcohol and rape-seed oil originally pre-

scribed by Bechi); the temperature reaction with ten cc. concentrated sulphuric acid (sp. gr. 1·84) and fifty grams of oil; the melting point of the fatty acids obtained by saponification of the oil, and the elaidin test as described by Allen, will prove conclusively the presence of cotton-seed and almost certainly differentiate the other oils that could be present. The accurate determination of the specific gravity by weighing is generally important, and the presence of any unsaponifiable matter should be noted. The color test by nitric acid may, in some cases, prove useful as also the pure sulphuric acid color tests. All, or nearly all, the other very numerous color tests that have been proposed and used are said to be unreliable or absolutely useless in a mixture of oils of a miscellaneous origin. Other tests may be applied as indications seem to suggest.

My experiments gave results as follows:

I obtained three-pound cans of leaf lard, said to be entirely pure, from each of two well-known lard manufacturers in this city, out of freshly made stock and also a quantity of country lard from a farmer who was accustomed to supply my family with lard. Portions of each of these samples were examined for impurity or adulteration. They all responded satisfactorily to the usual tests for pure unadulterated lard. I did not test the lard by Bechi's test, but subsequently examined the oil by that method. I then pressed out the oil from these separately, using for this purpose a small screw press of the kind made for drugs. The temperature of the room was regulated so that it never exceeded 55°, nor fell below 45° F. Most of the time it stood slightly below 50° F. The pressure was applied gradually, and increased to the utmost that the press was capable of standing. The press was wiped dry after each experiment, and each oil sample was bottled separately.

The samples of lard before expression gave the following results to tests:

	Melting Point.	*Iodine Absorption, Per Cents.*					
Lard No. 1, ...	45° C.	62·9	62·1	61·9		average,	62·3
Lard No. 2, ...	45°	62·65	62 12	62·76	62·42	"	62·49
Country Lard, ...	33°*	59·24	59.42			"	59·33

* This figure is too low.

The country lard was much softer than the others, which fact corresponds with the melting point above given.

These iodine figures correspond nearly with those given by Hübl and others. Hübl gives two determinations in his original paper, viz: 57·6 per cent. and 60·0 per cent. (*vide* also E. W. T. Jones, *Analyst*, **13**, 170). In this country, chemists give a somewhat higher figure for American lard. Thus, R. W. Moore gives 61·9 (*Amer. Chem. Journal*, **6**, 417) and Prof. H. W. Wiley, United States Department of Agriculture, Division of Chemistry, *Bulletin* 13, part 4, p. 418, states that the mean percentage for prime steam lards is 62·86, and for pure lards of other kinds 62·48 per cent. The higher percentage for American lards is accepted by English chemists (*vide Analyst*, **13**, 169). Wiley also states, however, that lard rendered from different parts of the animal gives different iodine absorption percentages, according to the amount of olein contained in it. Thus, a sample of intestinal lard absorbed 57·34 per cent.; leaf lard from the same animal, 52·55 per cent.; foot lard, 77·28 per cent.; and head lard 85·03 per cent. But, as the lard now manufactured in this country is more or less of fat from parts of the whole animal, it has usually an iodine figure closely approximating to 62 per cent. English and other foreign lard is still strictly omentum, or leaf lard, which was the old-fashioned article of this country twenty or thirty years ago.

(1) The lard oil made as above stated from lard No. 1 gave the following percentage absorption of iodine:

74·54; 75·22; 75·95; 74·91; 75·09. Average, 75·14 per cent.

(2) The oil pressed out from lard No. 2 gave results as follows:

73·68; 73·06; 72·52; 72·96; 72·91. Average, 73·03 per cent.

(3) The oil made from the sample of country lard gave:

70·12; 70·45; 70·39; 69·72; 69·33. Average, 70·01 per cent.

Oil No. 1,	contained free	fatty acid	0·86	per cent.,	calculated	as oleic acid.
" 2,	"	"	0·49	"	"	"
" 3,	"	"	1·35	"	"	"

Average percentage of iodine absorbed in all three oils together is 72·72 per cent.

In a sample of extra prime lard oil, obtained from a dealer in this city, manufactured in Chicago, but guaranteed to be strictly pure by the Philadelphia firm, gave results as follows for iodine absorbed:

73·10; 75·09; 74·03; 73·88. Average, 74·02 per cent.

This sample had an acidity equivalent to 0·85 per cent. oleic acid. All the above examinations were made about five years ago.

Recently I have re-examined the identical samples of oils above-mentioned to learn if any change had taken place in the iodine absorption percentage during a period of five years in a corked bottle, part of the time exposed to diffused light and part of the time kept in a dark closet, the corks being occasionally removed, the bottles warmed up to liquefy the chilled oil, and portions removed. The oil made from lard No. 1 now gives me iodine absorbed 72·34 and 72·33 in consecutive tests. The extra prime lard oil of Chicago manufacture now gives me iodine absorbed 73·73 per cent.

The acidity for these oils does not appear to have altered much, but has not yet been determined quantitatively.

There seems, therefore, to have been no change of iodine absorbed beyond the limits of experimental error.

PROCEEDINGS

OF THE

ELECTRICAL SECTION,

OF THE

FRANKLIN INSTITUTE.

[*Proceedings of the stated meeting of the Electrical Section, held Tuesday, June 2, 1891.*]

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, June 2, 1891.

Prof. EDWIN J. HOUSTON, President, in the chair.

Present, twenty-six members and visitors.

The minutes of the previous meeting were read and approved.

The treasurer presented bills for printing and clerical work, which were ordered paid when approved.

Four nominations to membership were referred to the committee on admissions. This committee reported three elections since last meeting.

The secretary announced the death of Mr. David Brooks, active member, and upon motion a committee consisting of Messrs. C. Hering, Arnold and Wahl was appointed to draft suitable resolutions, and report them to the Institute as the action of the Section.

Mr. G. H. Almon read a paper on "Lightning Arresters." Referred for publication.

Prof. H. S. Hering concluded the results of his experiments on "The Effect of Atmospheric Pressure on Batteries." This and his former communications on the same subject were referred for publication.

Dr. Wm. H. Wahl exhibited and described an incandescent gas lamp, invented by Mr. Lungren.

There was discussion on this and similar lights by Profs. Houston and Rondinella and Mr. Billberg.

Mr. C. Billberg described a new time switch for electric motors, and exhibited a model in operation.

Mr. Carl Hering exhibited and explained a portable photometer for measuring illumination as well as candle-power.

The Question-Box contained queries concerning the magnetic polarity of drills, the deterioration of copper wire from a long-continued current of electricity, and the proper rise of temperature to allow in a well-designed dynamo. These elicited much interesting discussion.

The meeting then adjourned.

L. F. RONDINELLA, *Secretary.*

DAVID BROOKS.

[At the stated meeting of the Institute, held Wednesday, June 17, 1891, the Secretary presented the following memorial of the late David Brooks, prepared by a special Committee of the Electrical Section. The meeting thereupon approved the memorial, and directed its reference to the Committee on Publications.]

David Brooks, one of the most widely-known electricians of the day, one of the early telegraphers, and for many years an active and useful member of the Franklin Institute, died May 31, 1891, at Germantown, in this city.

Mr. Brooks was born in Brooksvale, Conn., January 26, 1820, and traced his descent directly from Henry Brooks, who emigrated with his family from Cheshire, England, in 1640, and settled in Cheshire, Conn., so named by his children from their native town, and there, and in the portion of the town known as Brooksvale, which bears the family name, the family is still represented.

The name of David Brooks is perhaps more intimately associated with the development and improvement of telegraphic communication than that of any other electrician of America, save Morse, his professional association with this epoch-making branch of electrical engineering dating back to the very beginning of telegraphy in the United States, and continuing actively down to the time of his lamented death.

The principal incidents of his professional career are briefly stated in the following:

After leaving college, at the age of twenty, he became instructor in mathematics, in the United States Navy. In 1845 he left the service and began that association with telegraphy which continued throughout his long and active career.

His first engagement in the telegraphic field was in conjunction with Mr. James D. Reid, to put in service the tele-

graph line between Lancaster and Harrisburg, in this state, which is claimed to have been the first commercial line constructed and operated in the United States, after the successful demonstration of Prof. Morse on his experimental telegraph line between Washington and Baltimore. In the following year, he superintended the construction of the line across the Alleghenies between Pittsburgh and Philadelphia, for the Atlantic and Ohio Telegraph Company. In 1847 he is credited with the invention of the earliest repeating instrument, known as the "Button Repeater," which was used with success.

In 1850 Mr. Brooks was appointed by the United States Court to prepare an opinion as an expert upon the Morse and the Bain systems of telegraphy, which opinion was frequently cited in the course of the litigation that followed.

In 1851, Mr. Brooks was engaged with construction of the first telegraph line in Mexico, between Vera Cruz and the City of Mexico. Upon his return to the States in 1852, he was engaged by the Pennsylvania Railroad Company, as the superintendent of the company's telegraph lines between Philadelphia and Pittsburgh.

In 1854 he became superintendent and manager of the Atlantic and Ohio Telegraph Company. This position he held until 1862, when the company was absorbed by the Western Union Company. He held the position of district superintendent at Philadelphia, with the company, until 1857, when he resigned.

Since then and until his death, he devoted his energies to the development of a number of inventions for the improvement of the telegraph service, which have made his name well known throughout the world.

In 1873 he was named by President Grant as one of the Commissioners of the United States to the Vienna International Exposition, to report upon telegraphic instruments. His report appears in the official publications of the Government on the exhibition, and constitutes one of the most useful and practical contributions of the series.

The most important of Mr. Brooks' inventions relate to the subject of insulation. He was the first to appreciate

and to apply the now universally acknowledged superiority of paraffine for this purpose; and his paraffine insulator for telegraph lines has been widely introduced throughout the United States and in Europe.

He was also among the first to appreciate and to advocate the system of underground lines for telegraph and other electric wires, and his application of the high insulating qualities of the mineral oils, and other liquid insulators for such lines has proved highly successful. The latest improvement in his liquid insulation for underground lines was the substitution of heavy rosin oil for paraffine oil used before. The results were exceedingly encouraging.

Mr. Brooks' services to electric science were recognized early in his professional career by his election to membership in a number of prominent scientific societies at home and abroad. He was elected a member of the Franklin Institute in the year 1867, and was actively interested in the work of the Institute almost to the day of his death.

He was especially interested in the Electrical Section, of which he was one of the founders, and the last technical contribution of his life was made at the Section's stated meeting in May last, when he read a paper "On the Insulating Properties of Oils," which appears in the June impression of the *Journal.*

Personally, Mr. Brooks was a man of great amiability of character, and of commanding presence. By his death the Institute has lost one of its most active and distinguished members, and the world of science one whose inventions have contributed in no small measure to advance the art of telegraphy to its present state.

CARL HERING, *Chairman.*
CRAIG ARNOLD,
WM. H. WAHL,
Committee of the Electrical Section.

BOOK NOTICES.

Hand-book of Calculations for Engineers, Firemen and Machinists. By N. Hawkins, M.E., 336 pp., large 8vo, with numerous illustrations. New York: Theo. Audel & Co., 91 Liberty Street. 1890. (Price, $2.50.)

This book is intended both for reference and instruction in the first principles of the science of steam engineering.

The opening parts teach, first, how to write and read figures; and from this elementary beginning the work proceeds to give the elements of arithmetic, mensuration, geometry, algebra, etc., all illustrated with examples of calculations relating to the every-day problems of the engineer.

Beginning with the elements of mechanics, in which the primary powers are mentioned and briefly described; the lever, wheel and axle, the pulley, and inclined plane are illustrated with figures, examples and descriptions.

Next follow, as general subjects, thermo-dynamics; horse-power, with copious rules for its calculating both of engines and boilers, and of every variety; pumps, with many practical points in their management and calculations; steam, description and figures relating to this main subject, injectors; gravity; strength of materials, with useful tables; the steam boiler; the safety valve, with many rules for ascertaining the safety limit of pressures; the steam engine, with illustrations and calculations, and description of varieties; engine counters; illuminating gas, and how to read the gas meter; tables of melting points of solids; electricity, how to measure and to calculate the numerous problems arising in its applications, with many useful points in its management; table of conductors and insulators of electricity; chimneys; transmission of power by belting and pulleys; the indicator, with illustrations and rules for figuring the diagrams; business points for engineers, and index combined with useful definitions. The work is published in ten parts, in paper covers, and the whole ten parts neatly and handsomely bound in one volume, cloth, making a book for the library 6 x 9 x 1⅜ thick. W.

Tables for the Determination of Minerals by Physical Properties, ascertainable with the aid of a few field instruments. Based on the system of Prof. Dr. Albin Weisbach. By Persifor Frazer. 3d edition, entirely rewritten. Philadelphia: Lippincott & Co. 1891.

The third edition of this standard work exhibits numerous evidences of careful revision. The general system of classification by physical peculiarities is retained, but the external characteristics of the mineral species have been more carefully described, and we notice a number of substitutions of new terms, to describe physical characters of structure, and the like, which are decided improvements. A most valuable feature of the tables, which will be duly appreciated alike by student and teacher, is to be found under the column of "Remarks," in which are stated in brief the principal and charac-

teristic reactions, with such specially distinguishing peculiarities which each species may exhibit, together with a list of its associated minerals. This column exhibits the exercise of much care and good judgment. The author has accepted the universally-recognized authority of Dr. Groth for the crystallization and chemical formulæ of minerals. A table of elements is given at the end of the work, based upon the latest revision of the atomic weights made by Prof. F. W. Clarke.

The book bears evidence of having been carefully proofread, since it is notably free from the typographical errors that frequently mar more pretentious works. W. H. W.

Franklin Institute

[*Proceedings of the stated meeting, held Wednesday, June 17, 1891.*]

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, June 17, 1891

JOS. M. WILSON, President, in the chair.

Present, 180 members and thirty-three visitors.

Additions to membership since last report, eight.

The Secretary submitted, on behalf of the Electrical Section, a memorial of the late David Brooks, which was approved by the meeting and referred to the Committee on Publications. [The memorial appears in this impression of the *Journal*.]

Mr. Mortimer McRoberts, of Chicago, read a paper descriptive of the Bevington process of welding metals, illustrating the subject by the exhibition of an extensive exhibit of specimens of copper, brass and aluminum, that had been submitted to the process. After some discussion of the subject of the paper, Mr. S. Lloyd Wiegand moved to refer the invention to the Committee on Science and the Arts for investigation, with the view of recognizing its merits by an award of one of the medals in the gift of the committee should it be found worthy. Carried.

Mr. S. Lloyd Wiegand, on behalf of the Committee on Science and the Arts, presented in abstract the work of the committee in the case of the Vauclain System of manufacturing Forged Car Wheels, as practised at the Baldwin Locomotive Works in Philadelphia.

Mr. F. E. Ives described certain improvements in his process of heliochromic photography, and exhibited a number of such pictures upon the screen, with the aid of the projecting lantern. The pictures attracted much attention and comment.

Mr. John Carbutt, in connection with this subject, spoke as follows:

"Mr. President: The demonstration we have just witnessed of the advance made by Mr. Ives in his heliochromic process in being able to show on the screen views direct from nature in all her brilliant colors, I consider by far the most important advance in this difficult subject; as obtained through the aid of photography, and notwithstanding the researches made by European scientists, I know of no results approaching what Mr. Ives has accomplished. I therefore move that the thanks of this meeting be tendered to Mr. Ives for his valuable illustration of heliochromic photography."

The thanks of the meeting were thereupon voted to Mr. Ives.

Mr. W. N. Jennings exhibited a series of interesting pictures of local subjects.

Mr. Carl Hering was chosen as the delegate of the Institute to the International Electrical Exhibition, at present being held at Frankfort-on-the-Main, and to the International Electrical Congress, to be held in connection therewith, and the President and Secretary of the Institute were authorized to issue a suitable document to Mr. Hering, certifying the fact over their signatures and the seal of the Institute.

Mr. Wm. E. Lockwood moved that the courtesies of the Institute be extended to members of the Association of American Railway Master Mechanics (and ladies), at present in session at Wilmington, Del., who may find it convenient to visit Philadelphia, and that the Secretary be instructed to telegraph an official invitation to this effect to the Secretary of the Association. Carried.

Adjourned. WM. H. WAHL, *Secretary.*

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INDUCTION OF ELECTRIC CURRENTS AND INDUCTION COILS.

BY PROF. ELIHU THOMSON.

[*A lecture delivered before the Franklin Institute, January 26, 1891.*]

The lecturer was introduced by Prof. Edwin J. Houston, and spoke as follows:

MEMBERS OF THE INSTITUTE, LADIES AND GENTLEMEN:

Since the memorable experiment of Faraday, about fifty years ago, by which he demonstrated that an electric current could produce another current by action called induction through the intervening space between the two conductors, an increasing interest has been attached to the phenomenon itself by the varied forms under which it occurs, the accompanying actions displayed and the utility of the apparatus.

One form of Faraday's experimental apparatus deserves particular notice, inasmuch as it contained the essentials of the much more modern apparatus of like character. It consisted of a ring of iron which had two coils wound on it, as seen in *Fig. 1.* He found that on passing a current through one coil there could be obtained a second or secondary current in the other at the moments of making and breaking the circuit of the first coil. These effects are now so well known that it is not necessary to dwell on them. They are examples of the phenomena of electro-magnetic induction, which Faraday investigated so ably and so thoroughly that he virtually laid the foundation for

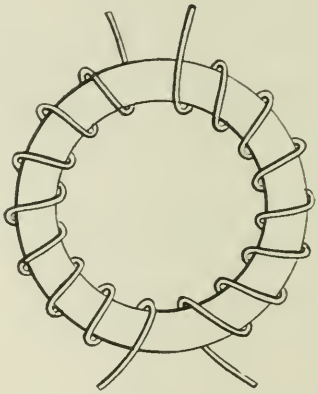

FIG. 1.

the dynamo machine, the electric motor of the present types, and the induction coil or transformer. Faraday's ring, with its two windings, is found, modified only to a slight extent, in the induction coils at present so extensively used in distribution of currents for lighting.

Long prior to these experiments of Faraday it had been known that an electrified or charged body brought near another body of conducting character, such as a metal ball on an insulating stand, would, under the inductive action of the charged body, become itself electrified, but in a special way, the nearest portion being electrified oppositely in kind of charge to the charge of the inducing body, a charge of like kind being repelled, as it were, to the more

distant portions of the insulated conductor. Without going into any consideration of these facts it will be sufficient to simply state that the principles of static induction enter into the construction of many of the most useful devices and apparatus of the electrician, chiefly in condensers.

In like manner it had long been known before Faraday's experiment that a magnet would produce other magnets inductively and give rise to changes of magnetism in other pieces of iron or steel merely by its presence near them. The experiments of Faraday showed the actions of electric currents to be similar, in that under certain conditions a current of electricity could develop a current in an adjoining conductor, or if such a conductor were not a complete circuit that it could develop charges of opposite name on

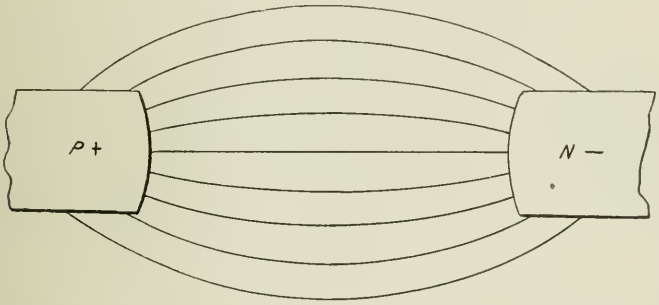

FIG. 2.

two parts of the conductor. Moreover, he showed that these effects were due not to any direct action of the current working at a distance, but in fact to the production of magnetism in the medium surrounding the conductor.

In *Fig.* 2, let P represent a charged conductor, and N another conductor connected to earth brought near to it or within a certain distance. There will at once arise a static inductional effect, whereby if P is + or positive, the body N becomes — or negative, and lines of inductional stress or electrostatic stress may be conceived as joining the two bodies as shown.

This figure will equally represent the effect of bringing an iron body N near to a magnetic pole P, in which case the lines would represent the lines of force or magnetic

lines joining the two. But suppose that the bodies *P* and *N*, when in the condition as first stated, that is, with an electrostatic stress existing between them, and, therefore, possessed of opposite electrical charges, be joined by a wire, as in *Fig. 3*.

Now, it will be found that a current will flow in the wire as assumed from *P* to *N* though the direction is a convention at present. An action in the wire occurs which we call the flow of the current and this flow continues so long as there exists any stress as represented by the lines joining *P* and *N*. But the moment of the beginning of current flow is attended by the evolution or formation of a system of forces or actions called magnetic actions and they are represented by closed bands surrounding the wire convey-

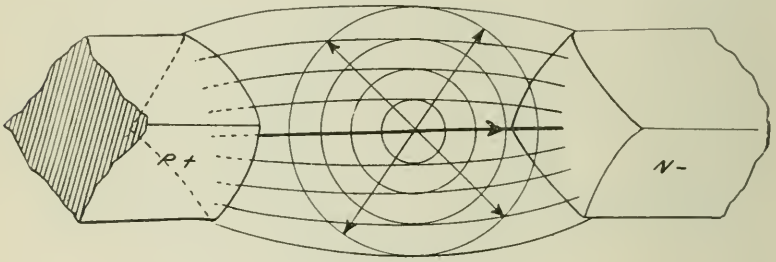

FIG. 3.

ing the current. They are at right angles at any point to the lines of electrostatic stress, and the influence which they represent proceeds outwardly from the conducting wire in a direction at right angles to both the magnetic bands or lines and to the lines of electrostatic stress and with a velocity equal to that of light, if the influence is unretarded.

The magnetic bands or whirls are the lines of magnetic force of Faraday. We then have three things at right angles, just as in space we have length, breadth and thickness, or distance. Can it be possible that in these conditions of electrostatic stress, magnetic lines, and propagation with the velocity of light, we have an exemplification of the properties of space of three dimensions, such that if we fully understood the one we would understand the

other? This is a view which is not improbable, seeing that the ether, or universal space-filling medium (or space maker perhaps), is known now to be the electrical medium.

Here then we have a harmony of effects pointing clearly to a common cause for all these actions of static induction, magnetic induction and current induction. Indeed, to-day we have learned to regard an electric current in a wire or conductor as simply a part of the thing occurring, the core, as it were, of a disturbance not limited to the wire itself, but extending outwardly therefrom in weakening force to limitless distances, and that the energy transferred by a current in a wire is conveyed, to use a sort of contradictory statement, by the medium outside the wire.

In short, we have come to believe more fully than ever before in the existence of that mysterious, all-pervading medium, the ether, and that magnetism, electricity—both static and dynamic—light and radiant heat, are things connected closely with the properties of the ether, which as a medium may be called broadly an electrical medium. We are accustomed to look to this medium also as the cause of gravitational effects. but by virtue of what property produced, and how produced, we know not. In like manner molecular and atomic attractions, cohesion and chemical affinities must be dependent on the properties of the ether, and cohesion may probably be gravitational force intensified by proximity in obedience to some unknown law. These considerations are, however, not explanations of these obscure yet most familiar phenomena.

It is not our purpose, in the present lecture, to do more than point out some of the more important effects produced by electric currents acting inductively, aside from other forms of induction, and to point out the great importance which these effects and the apparatus which yield such effects have come to occupy in the study and practice of the electrical arts.

In particular, we desire to deal with the inductive actions of those currents, the direction of which is constantly changing and at varying rates of change. Such currents are called alternating currents, the number of times per second

that the reversal takes place being called the rate of alternation, and half that number being known as the periodicity or frequency.

While the consideration of the actions occurring in magneto- and dynamo-electric machines would not be excluded by the title of the present lecture, since in such apparatus we have a case of electric current induction, yet it is thought best to confine ourselves to the consideration of the special instances in which one electric current sets up other currents or acts inductively.

Let us take first the case of a simple long wire or portion of an electric circuit through which a battery current may be sent by closing a contact or key. Close observation would show that such current did not rise at once or immediately to its full value but was very slightly delayed unless the wire were very long, in which case the delay would be quite considerable. It will have suffered an impeding action or "impedance," as it is now termed. This was Faraday's "extra current on making," in opposite direction to the current itself. Winding the long wire into a coil was found to increase this impedance and putting an iron core into the coil still further increased it. While in small coils or short conductors the action is of very slight duration, ending in a small fraction of a second after closing the circuit, yet in large coils with massive iron cores the impeding action may last a few seconds. In these cases it is said that the current develops a counter pressure to its own flow, or a counter electro-motive force.

Now let us consider the current flowing at its full value and an attempt to open the circuit or cut off the current. We have again a delaying action, a tendency of the current to force a brief continuance of its flow or to fall off gradually. This is manifested by a spark at the opening contacts which, with long and large coils, may become a flame of several inches in length. This was Faraday's "extra current on breaking"—more properly a continuance of flow resulting from a negative impedance, or addition to the pressure or electro-motive force of the current.

This effect is employed in many forms of apparatus, a

good example of which is the extra current coil or spark coil used in gas lighting by electricity. In this case a weak battery current is closed through a coil of wire wound on an iron core and the circuit carried to the gas burner, where, upon turning on the gas, the contacts at the burner are briskly separated, so as to cause an extra, current spark, which lights the gas. The battery current alone would not yield a spark of sufficient length and heating effect, and so the coil and core are introduced into the circuit. We find, in addition, that these actions are the more intensified the greater the capacity of the circuit for magnetic effects and changes. Hence, the presence of a large iron core which can gain and lose magnetism in accordance with the rise and fall of current, greatly enhances these effects, which are called oftentimes self-inductive effects, because the current itself produces them on itself. The magnetic changes, indeed, appear to be the cause of the impedance. A gain of magnetism in the surrounding medium causes a back pressure, which slows the current when put on, and a loss of magnetism causes a forward pressure or addition to the pressure of the current, which has the effect of prolonging the flow at diminishing amount and preventing absolutely sudden stoppage.

The study and knowledge of these simple facts are of the greatest importance in all departments of electrical work, from telephony to electric railways, and the property of impedance is either a bugbear or a welcome assistance in the solution of many electrical problems.

Naturally, when a current which alternates in direction many times a second is passed in a coil there is produced an impedance to the current in much more striking degree on account of the fact that such current may be considered to be a current which is started and stopped frequently, while the changes of magnetism are made much more pronounced by the reversals of the direction of current reversing the magnetic effects on which the impedance depends.

This action must not be confounded with resistance to a current, as it is altogether of different nature, for resistance has its effect whether the current change its amount or

direction or not, while impedance is present only with changing currents. The former is like a friction, the latter somewhat like inertia.

In telegraphy on very long lines with many instruments, impedance may limit the speed of transmission of signals. In telephony on long lines and with a number of coils or magnets in the circuit it softens, weakens and blurs the speech waves. Hence, in the improved telephonic instruments arrangements are made to cut out all coils unessential to speech transmission during the use of the instrument. In electric lighting with continuous currents the property under consideration, may, if not guarded against, cause damage to insulation on sudden rupture of circuits, or, on the other hand, it may be used to steady a current where such current would otherwise be subject to quick fluctuations.

Again, the property of impedance is slightly detrimental on long lines conveying alternating currents, but on the other hand it is of the greatest value in regulating and controlling the distribution of such currents, checking their flow and increasing such flow at will. Coils which may be called "reaction coils," "impedance coils," "choking coils," "kicking coils," are inserted into a circuit with alternating currents and act to cut down the current flow, not by their resistance (which is slight), but by their impedance, which may be made much or little as desired. Variable reactive coils, give a flexibility not otherwise obtainable. We must emphasize the fact that a resistance can check a current, but involves a loss of energy of the current, which energy is reduced to heat in the resistance, while a "reactive coil" can check the flow and cause loss of only a slight amount of energy in doing so. To Prof. Joseph Henry, it is believed, is due the discovery of this action of impedance in electric circuits, and a movement is on foot to call the unit measure of impedance the henry, in honor of this great electrician and scientist.

Suppose, now, that, having a coil wound upon a core, the structure is such that it gives a considerable reaction or impedance to the current. If we now wind a second coil

along-side the first and do not connect its ends to close its circuit, we shall find that the actions of the first coil are unaffected, but the moment we close the second coil there is a great change produced. Indeed, the impeding effect of the first coil is very much weakened, though it does not disappear. Here we have a case of induction of currents with another parallel circuit. We have, in fact, an induction coil, the secondary coil of which, as it is termed, is closed on itself and might be replaced by a set of rings around the first coil or a tube of copper, or the like. If we examine what occurs in the second or secondary coil, we will find that at every increase of current in the first or primary coil there is a current produced moving oppositely in the secondary, and on the cutting off of the primary there is a current in the same direction as the primary. The induction coil has long been known, and dates from Faraday's experiments, but those forms of it called Page's helix and the Ruhmkorff coils, have been used for a considerable period to obtain from a battery current sent intermittently through a primary coil of comparatively coarse wire, very high pressure discharges from the fine and long secondary wire wound parallel thereto. Such coils have also been used in medical coils in many modifications, and more recently in the transmitter boxes of telephones, to cause a low-pressure varying current to induce in the line circuit at high pressure a similar varying current representing the waves of speech.

The Ruhmkorff coil, however, in its improved and effective form, is not simply what I have described, but much more. There is a condenser of large surface attached to the primary coil on each side of the break or set of contacts which open and close the battery connection to it. The condenser, of course, is as usual simply extended surfaces of tin-foil separated by paper insulation, one surface being connected to one side of the break and the other to the other side. Its function has been described as being that of suppressing the spark, breaking the primary by taking into it the extra current or prolonged discharge which makes the spark. It not only does this, but being the

recipient of a charge in the same direction as the battery current, it discharges itself instantly thereafter and gives a reverse discharge through the primary coil. These actions are so very sudden that they amount to a very quick alternation of the primary current. Hence, the condenser is easily seen to greatly intensify the effects for which the coil is intended. It is well known that the condenser used may be made too small in surface or too large to give the maximum effects in any case.

With alternating currents passed through the primary coil the result is that we get alternating currents in the secondary coil. The applied currents are in the form of electric waves, which may be of a pitch of a few waves per second up to a large number. I have experimented with such currents up to 8,000 reversals per second, or 4,000 complete waves of current per second. In such cases the condenser is not needed, though it may under special conditions act in a measure to increase the pressure of the currents as it does in the Ruhmkorff coil. In fact, such effects have been noticed in the recent Ferranti undertaking in London, where the condenser effect of the mains for carrying the primary currents to induction coils has resulted in increasing the potential or pressure of current in London considerably above that existing at the station at Deptford, which station supplies the current. The effect, though unexpected and apparently anomalous at first, was readily seen to be due chiefly to the mains themselves acting as condensers.

Induction coils, as now used in electric lighting, are of a variety of forms and have been given a variety of names. They are sometimes called converters, or again transformers. It is a matter of taste whether one shall call them induction coils, which they are, or converters or transformers, though of the two latter names the term transformer is apparently more widely used. Such apparatus usually differs from the Ruhmkorff coil in having the secondary winding the coarser wire of the two, and, consequently, their function usually is to take a higher pressure current supplied from a station and lower it for use in working incandescent lamps on the local or secondary circuit.

The actions of transformers may be briefly described, though a book might easily be written extending into many interesting details of their structure and performance—most of which would be out of place here. The modern transformer consists of two coils and an iron core for the coils. The core may be a closed core, as when the iron of which it is made is carried over the outside and connected into a closed band or closed magnetic circuit, or it may be an open core, where the magnetism passes into the air in completing its path between ends of an iron core, which are separated some distance. These differences introduce differences of action, which will not be discussed now, as they are largely of a technical character.

Suppose, now, that such a structure has its secondary coil open or unconnected with lamps. In such case, if an alternating current be passed in the primary coil of the apparatus, it "reacts" only. It displays the action of impedance as referred to before. This, with a well-proportioned coil, limits the current which passes to a very small amount, which current, small though it be, does not even then represent a waste of current energy except in small part. If, now, a lamp be lighted by connection with the secondary coil the current required for it is induced from the primary, but this action partly takes away the impeding action, and, as a consequence, the current taken by the primary from the line is proportionally increased. This assumes the case of constant pressure of current on the mains, the condition aimed at in practice.

As lamp after lamp is added in multiple or parallel connection in the secondary circuit the primary impedance falls off, and is only restored when a corresponding increase in the primary current takes place, together with the increase of current in the secondary. This means that if one ampère of current produces ten ampères on the secondary at a pressure of one-tenth of the primary circuit pressure, each increase of an ampère in the secondary coil would cause an addition of one-tenth ampère to the current in the primary coil. Briefly, the reason for this is that since the current in the primary is subject to impedance due to magnetic

changes produced in the iron core, and the secondary current, as it increases, tends to lessen the magnetism and consequently the changes in it, the impedance to the primary current is likewise lessened and the primary current increases to an extent such as to overcome the opposition of the secondary currents and restore the varying magnetism to its original amount. In the majority of transformers, also, the current induced in the secondary is at any moment moving in the opposite direction around the core from that of the primary current waves, and so acts to oppose the effect of the primary in magnetizing the core.

It would take up too much time and carry us beyond the

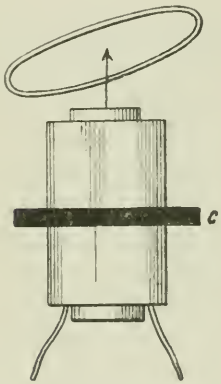

FIG. 4.

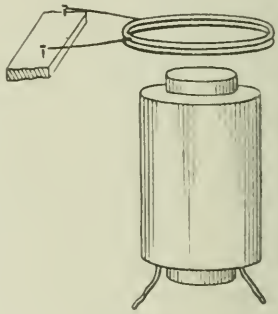

FIG. 5.

limits of the present lecture to study the effects of the lines of magnetic force in these instances. It must suffice to state that the actions of transformers are beautifully exemplified and made clear by such a study and the regulating actions just described are seen to depend on the interaction of the currents in the two circuits, occurring through the lines of magnetism or the magnetic field which they jointly set up.

In the case of a transformer put upon closed circuit, *i. e.*, with its secondary circuit or coil ends connected solidly together, the impedance or reaction in the primary almost disappears and if working as in practice, the primary and also the closed secondary circuit would receive current

in such large amount as to overheat and destroy the coils unless safety cut-off appliances were provided.

This is exemplified by an experiment easily tried. A closed ring of copper is placed over the upright coil and core *c*, *Fig. 4*, here, and alternating currents passed through the large coil which is now the primary. Currents of great vigor are set up in the closed ring and may rise to a value in heating effect such as to bring the ring up to bright redness, or even melt it. The energy is abstracted by the ring not from the air but from the ether surrounding the coil and core. If, however, the ring be free to move and not exactly over the centre of the coil and core it will be thrown

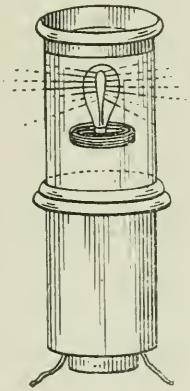

FIG. 6.

violently away or repelled and thus saved from overheating. These repulsive effects of induced currents are so striking and varied that it will be of interest to study them further.

It will be found that a copper ring or plate placed over the end of the coil, the core of which forms an alternating magnet, will even be supported for a moment in free air, or if guided laterally will remain suspended. The suspended ring will uphold one or more other rings placed near it, and will attract them into parallelism with itself, *Fig. 5*. Closed coils, pieces of metal, coins, etc., may be repelled from the field in this way.

A small incandescent lamp and coil, *Fig. 6*, suitably mounted and partly balanced in front of the pole, will be lighted and

at the same time be repelled in such way as to give a uniform brilliancy, whatever the strength of the current in the primary, or independently of variations of the same. If the lamp and coil be floated in water in a glass vessel placed over the alternating magnet pole the lamp is lighted and floated under the water by the repelling effect, and regulates its position and brilliancy as before. The magnetic waves leaving the pole, of course, penetrate the glass and water without hindrance. Interposing a heavy plate of copper between the pole and lamp coil will cut off, or screen off the effect, for the reason that the magnetic waves are then intercepted by the heavy sheet and beaten back or reflected by it. From these experiments it will be seen that there is a strong repulsive effort exerted between the primary and secondary coils of a transformer where the two lie adjacent on the same core. The reason of the repulsion has been discussed in various publications, and been shown by me to be due to lag or displacement of phase, as it is termed. Briefly, it depends on the fact that the primary and secondary currents are for the most part in opposite directions of flow around the core during each wave of current, and each current tending to produce a magnetic field which opposes that of the other, results in repulsion of the coils or circuits in which such oppositely moving currents circulate.

Following a suggestion of the Secretary of the Institute, I have improvised an experiment which I am told is very similar in effect to a "mystery" shown in connection with a "certain motor" which has been before the Philadelphia public for the past seventeen years. I bring forward this experiment with no hope that it will revolutionize modern methods or give us power for nothing, as the certain motor, or perhaps uncertain motor, is claimed to be able to do when developed. On the table is a tall glass jar, a sort of hydrometer jar, which was found in the room adjoining this hall. It rests on a table or rather on a heavy glass plate laid on the table, as you see. In the jar is a body which has sunk to the bottom of the water which fills the jar. It is a glass bulb loaded with a few turns of bare copper wire coiled up and heavy enough with the bulb to just

sink. At my command you see the body rise briskly to the top of the water, a distance of twelve inches, and sink again at my indication that it shall so act. I have no need to sound "sympathetic" notes or "antipathetic" notes as I am informed is sometimes done in connection with the "certain motor mystery," which no one is allowed to investigate. My assistant simply closes or opens a switch which sends an alternating current into or cuts it from a concealed coil just below the table top, a coil which I found as a part of the stock of insulated wire in an electric supply shop near this hall. I have taken no especial pains with this experiment and I am informed by Dr. Wahl, your Secretary, that the effect is strikingly like the "mystery" alluded to above. There are other ways possible in which such an effect might be obtained by simple means, but their discussion would be foreign to the subject in hand.

Some time after I had discovered this repulsive action and prepared to investigate it more fully, it occurred to Mr. M. J. Wightman, an associate, and myself, to try the effect of closed circuits or bands subjected to the induction of an alternating magnet, on copper discs, bands, or pieces of iron. It was reasoned out that these would move if allowed to do so. A great variety of novel and striking experiments was the result, some of which it is my purpose to present. They admit of almost indefinite extension and amplification; and it would not be possible in the time of the lecture to do more than allude to the explanation of some of the more typical actions.

They may for the greater part be regarded as effects of movable secondary circuits of induction apparatus.

Taking our upright core and coil, and placing over a plate or ring of copper *S*, *Fig. 7*, so that the centre of the ring or plate does not coincide with that of the pole, we have a magnetic field resulting which possesses novel and interesting properties. I call the pole a "shaded" pole or pole of shifting magnetism. It may otherwise be described as a pole in which the shaded portion of the magnetic field is lagged at each impulse of current in the coil behind the portion unshaded or free.

Naturally, the shading of the pole may be of a simple or complex character, as desired.

Placing a pivoted disc *D*, of copper, flatwise over the shaded pole so that its axis is to one side of the pole and approximately in line with the division between shaded and unshaded portions results in rapid rotation of the disc towards the shaded portion, *Fig. 7*. The direction of revolution of the disc may therefore be governed by shading the pole to the right or left of the axis of the disc. An iron disc *I*, *Fig. 8*, is revolved if held vertically over the region of the pole shaded by the closed ring or plate, or over any part of the pole near the junction of shaded and unshaded portions.

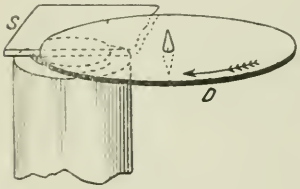

FIG. 7.

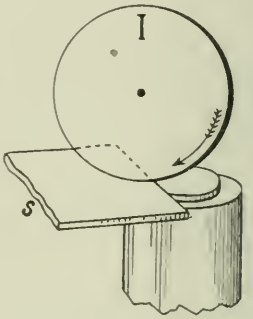

FIG. 8.

Two copper discs, laid one overlapping the other and free to turn, *Fig. 9*, and directly over the pole (in this case unshaded), are both set into rapid revolutions in directions depending on their positions over the pole.

These experiments with one or more discs and with shaded and unshaded poles may be greatly extended and a great variety of effects of rotation produced. Copper and iron discs may be used together and caused to rotate by their mutual influence on each other in the field. In this case the discs are generally placed in planes at right angles, the plane of the copper being transverse to the magnetic lines leaving the pole, and the planes of the iron disc being in line or coincident with their direction.

The copper discs may be replaced by hollow balls, *Fig. 10*, which rotate in a variety of ways. Thus, by shading the pole

and placing a copper ball over the shading plate, the ball is vigorously rotated on an axis depending on its relative place over the pole and shading plate. A certain thickness of shading plate gives the best results. The ball may revolve on a horizontal axis or with its axis either inclined or vertical. When turning with its axis horizontal it rubs its equatorial portion at great speeds over the shading plate.

A modification of this experiment is made by placing the ball in a vase of water supported over the pole shaded as before. In this case the ball rotates vigorously in the water. If a copper dish be added, and a second ball, all

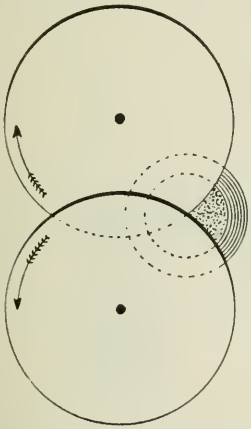

FIG. 9.

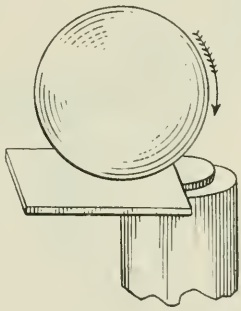

FIG. 10.

three may be maintained in a vigorous and confused activity by the shaded pole. The actions in the disc and balls are the direct consequence of the shifting magnetism of the pole, whereby as it were the lines of force act as veritable magnetic brushes to brush the discs, balls, etc., around. The hold which the lines get in the copper in causing its rotation is, of course, due to the production of induced currents in it by the moving lines of magnetism or developing field. The effect on the iron discs is due to magnetism rather than to current, the iron discs resisting slightly a change of direction of magnetization in them, which results in the shifting lines dragging the discs

around in the direction of shift or towards the delayed or shaded portion of the pole.

Some of the most curious effects are obtained by placing various shapes of iron or steel pieces over the pole and then testing them with the approximated copper or iron discs, *Fig. 11.* Few dispositions will fail to cause rotation of the discs. A more sensitive rotator, however, is a shaft mounted on delicate pivots and carrying a wheel composed of a few small discs of sheet-iron with an attached heavy copper rim overhanging the iron discs, and shown in section, *Fig. 12.*

If this device or if copper or iron discs alone be applied in the proper way in the neighborhood of pieces of iron, copper, or even brass laid on the pole, rotative effects are

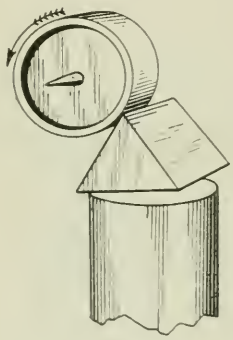

FIG. 11.

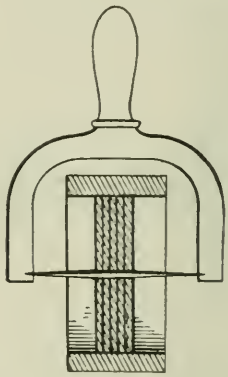

FIG. 12.

readily obtained. Thus, a steel file laid over the pole, as in *Fig. 13*, will rotate the iron discs in the direction of the arrows when they are mounted as shown, and copper discs are rotated likewise when placed near and flatwise to the file.

In this case the hardness of the steel of the file compels the magnetic change of polarity, originating at the pole, to spread laterally in a retarded manner similar in effect to the shading spoken of, but differing in cause. The shading plate of copper acts by the currents developed in it; the steel mainly by its hysteresis or resistance to changes of magnetic state, an inherent property of hardened steel.

Bent pieces of steel laid over the pole vary the actions in many ways that are quite interesting.

As a curious example of a combination of electric and mechanical actions in one device, we have an electric gyroscope constructed of a copper-rimmed rotator with iron plates or discs mounted on a shaft, a closed circuit frame of copper surrounding the same and an arm with jewel cup and counterbalance weight. This is mounted, as shown, over the alternating pole on a steel pivot set therein. Very soon the wheel of the gyroscope is set into rapid rotation and then the apparatus exhibits all the characteristic movements of the gyroscope, independently of the electric actions.

The fact that in the actions described above we obtain motion of rotation or translation is sufficient to indicate

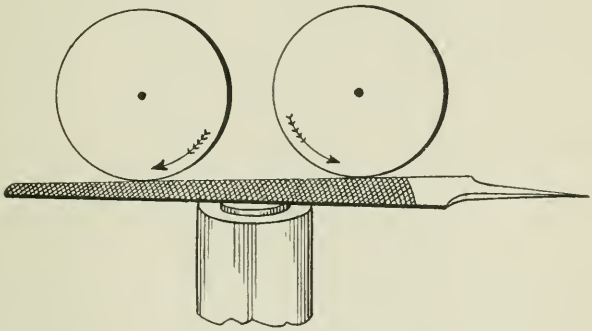

FIG. 13.

that electric motors operating by alternating currents may be constructed in accordance with the same principles. Alternating current meters have also been made in which the rotary actions have been employed to move a register at a rate depending on the current flow or consumption.

I have here one example of a small motor in which the moving part is a heavy copper disc entering the slot in a ring core upon which is wound a coil traversed by the alternating currents. The magnetic poles on each side of the slot are shaded progressively from the under side up by enclosure in copper bands let into the face of the poles. A considerable rotative force is thus obtained. Removing the disc armature of this motor and placing a silver coin at the lower edge of the slot results in the coin being lifted up and

projected from the slot above. A disc of base metal, such as lead, is not so projected while a copper disc behaves like the silver. The instrument might be arranged to quickly sort genuine silver coins from base coins, though a silver-plated copper coin would be affected about in the same manner as the alloyed silver, but pure copper would be lifted somewhat farther for the same weight and diameter of disc.

These experiments are primarly based upon the alternating magnetic field set up by an alternating primary current in a coil, and which field is modified by closed secondary coils or circuits, or by the presence of steel pieces in the field in such a manner that a portion of the field develops its effects before the other. To put it differently, a lag is set up in a portion of the field. The closed coils or plates used as secondary circuits have currents induced in them which oppose the magnetic changes tending to be brought about by the primary currents and delay such changes in that portion next to the said secondary circuits. In like manner the presence of hard steel pieces which resist change of magnetism have a similar effect in retarding the development of magnetism at each change of its direction, at the place where such pieces exist, while all around them in the air the field is comparatively free to obey the primary impulse. There results from these conditions a propagation, so to speak, of magnetism or magnetic polarity which may act on other closed circuits, or on other pieces of iron or steel to set them in motion. The movement so obtained is brought about by the continual readjustments of the moving secondary or iron piece to the shifting or propagating magnetism.

The copper rimmed iron wheel, *Fig. 12*, is so delicate a detector of shifting magnetism, that it responds to the effects of any feeble shifting which may occur in the iron core around which the primary current passes. In fact, different forms of core, whether of iron wire bundles, or of laminated structure, as bundled sheet iron, each give their own peculiar effects of shifting magnetism in accordance with the form, material and relation of the parts, and their

liability to eddy or foucalt currents or hysteresis in various positions or directions. Few cores indeed fail to show decided effects of shifting lines of magnetism at some portion of their surface, and a laminated core may be readily distinguished from a wire core by this little wheel, delicately mounted. In fact, it may be regarded as an alternating field explorer, and its indications may be of considerable value in locating sources or conditions of loss by foucalt or eddy currents, or by hysteresis.

It has been necessary to be brief in the descriptions given in this lecture, as the time has been too limited to do more than furnish food for study to those who are sufficiently interested in this important subject of current induction, in which so many developments have taken place in the recent past. The future has, of course, very much more in store.

The RANGE of TIDE in RIVERS and ESTUARIES.

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When tidal rivers or estuaries are improved by means of works of restriction, it frequently happens, in consequence of such improvement, that the volume of discharge is diminished, not only on account of the superficial area of the river having been decreased, but also on account of a diminution of the range of tide, caused by the greater resistance, which the restricted bed offers to the passage of the tidal wave.

In the river proper, the evil consequences arising from this loss of volume are, generally, more than counterbalanced by the beneficial effects of restriction; but in the entrance the decrease of discharge frequently has undesirable consequences. Here, restriction may be difficult or entirely impracticable, and if so, then the possibility of maintaining the channel over the outer bar diminishes in the same ratio in which the volume discharged over it is diminished.

Hence, it may be said that in many cases the improvement of the river proper and the maintenance of the entrance are in a measure antagonistic to each other. The employment of the means best adapted to achieve the former is apt to be followed by consequences detrimental to the latter. A similar relation exists between the improvement of the entrance by restriction and the maintenance of the channel in the river above, and it is an important part of the task of the engineer to find, in each case, the best possible way of reconciling with each other, these conflicting interests.

One of the first questions then presenting itself in connection with the improvement of tidal rivers and their entrances, is whether or not the proposed works of restriction are apt to exercise an unfavorable influence on the tidal range of the river. While experience and good judgment will, *generally*, enable the engineer to make a sound forecast in this respect, it cannot be said that this can always be done with that certainty which the importance of the subject seems to demand. It is evident that there would be no difficulty about any such forecast, if the conditions governing tidal phenomena in rivers and the influence exercised by each of them were known. In the following, an attempt has been made to solve this question.

A tidal wave entering a river or an estuary will have its range diminished in moving upward, until it is either gradually obliterated or its further progress arrested by an impassable barrier.

This general course of events is, however, subject to modifications in each individual case, so that probably there do not exist two rivers, the tidal phenomena of which are precisely the same. In some cases, the range of tide decreases rapidly; in others, gradually. Again, it often remains unchanged for a long distance, and sometimes it even increases before the final deterioration begins.

The estuaries of the Hudson and of the Delaware, for instance, are entered at Sandy Hook and between the Capes, respectively, by tidal waves of about the same range. In the former, there is a *decrease* in range of about one-third

during the first forty miles of its upward course, while in the latter, there is within twenty miles of its mouth an *increase* in range of about the same amount.

The inference that such and similar differences are caused by the individual features of the river-beds in which the tidal waves move appears justified; and it further appears probable that, generally speaking, the most important influence is exercised by the relation between the capacity of the river-bed and the amount of service it is called upon to perform. The capacity of the river-bed is represented at each point by the cross-sectional area of the river, and the amount of service it is called upon to perform, by the superficial area of the tidal basin above. The quotient of these two may then be supposed to be a measure of the possibilities of the tidal range above, up to a point where the slope of the river bottom becomes so steep that it exercises a perceptible influence on the further progress of the tidal wave. In a general way, this line of argument is sustained by the fact that, where an increase of range takes place, we find comparatively great cross-sectional areas and small extent of tidal basin above, while, *vice versa*, where a very marked decrease of range takes place, we find comparatively small cross-sectional areas and great extent of tidal basin above. The Raritan River in New Jersey is a fair example of the former case, while the St. John's River in Florida is a striking illustration of the latter.

In order to develop, on the basis outlined above, a mathematical expression for the conditions of the river bed required for a propagation of the tidal wave with undiminished range, a comparison was made between the following rivers, for each of which more or less detailed data were available:

(1) Hudson.
(2) Delaware.
(3) Elbe.
(4) Clyde.
(5) Raritan.
(6) Savannah.
(7) Weser.
(8) Seine.
(9) Nansemond.
(10) James.
(11) St. John's.

The high-water cross-sectional area of each river was determined at as many points as the available data would allow, and for each such point the superficial area of the tidal basin above was computed; the former was then divided by the latter, and to avoid cumbrous decimal fractions, the quotient was multiplied by 1,000,000. Now, other things being equal, the same quotient must correspond to a greater loss of range in the case of a higher range than in the case of a lower range. In order to make possible a comparison between different rivers with different tidal ranges, the figures thus obtained were, therefore, reduced to a common basis by dividing each of them by the tidal range pertaining to it.

We designate, as follows:

A, High-water cross-sectional area in square feet at any point.

R, Mean tidal range in feet at the same point.

S, Superficial area of tidal basin above such point expressed in millions of square feet.

We then have for C, the above described coëfficient, at such a place—

$$C = \frac{A}{R\,S} \tag{1}$$

Coëfficients found according to this expression were obtained for as many points as possible, and means of them were taken for those stretches of river on which the rate of decrease or increase of range remained the same. From the results thus obtained, which are rendered in the appended tables, it appears that, generally speaking, to the greater coëfficient there pertains the greater tendency towards constancy or even increase of tidal range, with this qualification; that the coëfficient remaining the same, the approach to constancy or to increase of range will be the closer the greater the cross-sectional area.

A striking verification of this is found in the case of the Savannah River. Besides the mean ranges at the various places, there were available 345 rises and falls observed simultaneously at Fort Pulaski and at Fort Oglethorpe,

They were grouped according to their height, and the following means obtained from them :

Number of Observations.	Average of Observed Rises and Falls at. *Pulaski.*	*Oglethorpe.*	*Increase or Decrease of Range per 10 Miles and per Foot of Range.*
28	4·66	4·81	+ 0.046
36	5·50	5·47	0
49	6·02	5·91	— 0·027
60	6·51	6·31	— 0·050
64	7·01	6·70	— 0·067
62	7·71	7·16	— 0·109
46	8·89	7·94	— 0·166

It is seen from this table that for the smallest range, for which *C* of course is greatest, there is an actual gain of range, from the lower to the upper point of observation. Next comes a slightly greater range and, consequently, a smaller *C*, for which there is practically no change between the two points of observation ; and, after that, the loss in tidal range uniformly increases with increasing range and decreasing *C*.

In order to define clearly the influence exercised by the coëfficient and by the cross-sectional area on the tidal range, the results rendered on the appended tables were platted on the accompanying diagram, the coëfficients *C* being the ordinates, and the corresponding cross-sectional areas in square feet *A* being the abscissas. Wherever an unchanged tidal range pertains to these two, the point determined by them has been marked on the diagram by two concentric circles, and, wherever a decrease or an increase of range pertains to them, the point determined by them has been marked by a single circle. It will be seen that the various points of no change of range are so located that an equilateral hyperbola introduced on the diagram corresponds with them sufficiently well to warrant the conclusion that it represents approximately the curve of no change of tidal range. This conclusion is further sustained by the fact that the points of decrease and the points of increase are located as they should be, the former outside and the latter inside of the hyperbola.

The axis of ordinates (the coëfficients) and a line paral-

lel to the axis of abscissas (the cross-sectional areas) are the asymptotes of this hyperbola, and it now remains to deduce its equation from the general equation of an equilateral hyperbola, referred to its asymptotes, which is

$$xy = \frac{m^2}{2}$$

in which m is the half axis of the hyperbola. In the diagram, this has been made equal to fifteen units of the y scale, and we therefore have

$$xy = 112{\cdot}5 \text{ or } y = \frac{112{\cdot}5}{x}$$

This would render y in its own scale, if x were expressed in the same; and, in order to do this, we have to consider the relation between both scales, which is—

Length of one y unit = length of 5,000 x units.

Introducing this into our equation, we obtain

$$y = \frac{112{\cdot}5}{\frac{1}{5000}x} = \frac{562{,}500}{x}$$

Now the asymptotic x axis is distant from the zero line of the y scale twenty-three units of the latter. We, therefore, have

$$\text{Coëfficient} = C = y + 23.$$

Substituting this above and remembering that x and A are identical, we now find

$$C = \frac{562{,}500}{A} + 23$$

This, in connection, with equation (1) renders

$$\frac{A}{R\,S} = \frac{562{,}500}{A} + 23 \qquad (2)$$

or

$$A^2 - A\,S\,R\,23 = S\,R\,562{,}500$$

Solving for A, we obtain

$$A = S\,R\,11{\cdot}5 + \sqrt{S\,R\,562{,}500 + S^2\,R^2\,132{\cdot}25}$$

or, in a more convenient form

$$A = S R \left(11{\cdot}5 + \sqrt{\frac{562{,}500}{S R} + 132{\cdot}25}\right) \qquad (3)$$

which is an expression, in terms of the tidal range and of the area of the tidal basin, for the cross-sectional area required for a propagation of the tidal wave with undiminished range.

Solving equation (2) for S, we obtain

$$S = \frac{A^2}{R\,(23\,A + 562{,}500)} \qquad (4)$$

which gives the superficial area of tidal basin above a point lying on a stretch of river on which the tidal range undergoes no change. It should be borne in mind that while the units of A and of R in these equations are square feet and feet, respectively, the unit of S is 1,000,000 square feet.

The practical bearing of equations (3) and (4) is obvious. By means of them, within certain limits, we can decide the question as to which way the tidal range will be affected by contemplated works of improvement.

Supposing, for instance, the construction of training walls was contemplated at the mouth of the Clyde, five and one-fourth miles below Dumbarton Castle, then the fact would have to be considered that at present a tidal range of ten feet passes undiminished up the river. In order not to let the proposed training walls exercise an unfavorable influence on this present state of affairs, the opening between them, according to equation (3), should not be smaller than

$$A = 350 \times 10\left(11{\cdot}5 + \sqrt{\frac{562{,}500}{350 \times 10} + 132{\cdot}25}\right)$$

$$= 100{,}700 \text{ square feet}$$

Formula (3) can be applied in such cases also where the mean range does not remain constant on the river stretch in question. From the results found for Savannah River, it seems probable that in all such cases another height of range can be found which passes up the same stretch unchanged, unless, indeed, the changes experienced by the

mean range on this stretch are very great. In cases of *decrease* of mean range, this constant range will be *smaller* than the same; in cases of *increase* of mean range, it will be *greater*.

The meagre data that were available for this discussion are not sufficient to let the results appear as exhaustive, and the writer's exertions towards the collection of additional data will, therefore, be continued. If he succeeds to collect a sufficient amount of these, then it will probably be possible to construct on the diagram, besides the curve of "no change of range," curves of uniform increase and decrease, so that mathematical expressions can also be found for those cases in which the tidal range increases or decreases.

(1) HUDSON.

Locality.	*Distance from Mouth. Nautical Miles.*	*S. Millions Square Feet.*	*Mean A of Stretch. Square Feet.*	*R Feet.*	*Mean C of Stretch.*	*Change of Range per 10 Miles and per Foot of Range.*
Sandy Hook, . . .	0	8326·4		4·70		
Battery, ...	14	3726·4		4·40		
			170,000		14·3	— 0·10
Sing Sing, ...	42	2580·4		3·30		
			151,300		26·6	no change
Rondout, ...	92	1217·2		3·30		
Tivoli, ...	102	940·5		3·35		
			72,000		26·9	— 0·05
Catskill, ...	112	717·3		3·20		
Albany, ...	139·5			2·30		

(2) DELAWARE.

Cape Henlopen, .	0	20995		4·5		
			2,430,000		31·6	+ 0·14
Egg Island Light, .	20	8233		6·0		
			548,000		27·2	no change
New Castle Range,	55	1549		6·0		
			139,200		26·6	no change
Big Timber Creek,	82	495·3		6·0		
			75,000		30·6	no change
Five Mile Point, .	90	316·6		6·0		
			45,300		34·4	— 0·03
Burlington, . . .	102	167·0		5·8		
			17,600		36·5	— 0·27
Trenton, ...	114·5			4·1		

(3) ELBE.

Locality.	*Distance from mouth. Nautical Miles.*	*S Millions Square Feet.*	*Mean A of Stretch. Square Feet.*	*R Feet.*	*Mean C of Stretch.*	*Change of Range per 10 Miles and per Foot of Range.*
Schaarhorn, . . .	0			9·4		
Brunsbuettel, . . .	27·2	1982		9·1		
			206,000		22·1	— 0·01
Luehe, ...	55·3	432		8·9		
			65,000		26·3	— 0·31
Hamburg, ...	67·2	208		6·2		
			19,000		57·0	— 1·10*
Elbstorf, ...	85·2			0		

(4) CLYDE.

Mouth, ...	0			9·7		
Dumbarton Castle,	5·25	103·6		10·0		
			26,700		43·7	no change
Dalmuir Works, .	10·0	29·8		10·0		
			8,150		92·0	+ 0·13
Glasgow Bridge, .	17·4			11·0		

(5) RARITAN.

Sandy Hook, . . .	0			4·70		
South Amboy, . .	12·0	104·7		4·83		
			28,700		108·6	+ 0·14
French's Landing,	17·0	18·9		5·19		
			6,500		112·4	no change
New Brunswick, .	22·5			5·16		

(6) SAVANNAH RIVER AT MEAN RANGE.

Mouth, ...	0			7·0		
Lower end Long Island, ...	4·6	407		7·0		
			62,250		27·7	— 0·08
Lower end Wrecks Channel, . . .	11·6	160		6·6		
			14,500		18·2	— 0·62
Read's Mill, . . .	16·6	124		4·84		
Head of tide, . . .	38·4			0		

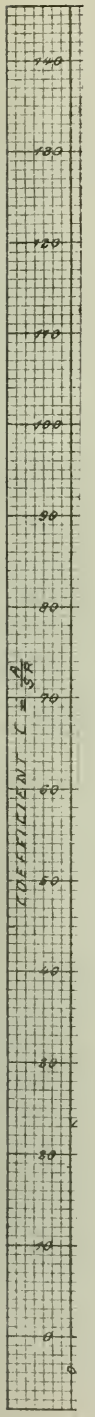
(6*a*) SAVANNAH RIVER AT LOW RANGES.

Lower end Long Island, ...	4·6	407		4·66		
			58,200		36·8	+ 0·05
Fort Oglethorpe, .	11·4	260		4·81		
Lower end Long Island, ...	4·6	407		5·5		
			60,200		33·0	no change
Fort Oglethorpe, .	11·4	260		5·5		
Lower end Long Island, ...	4·6	407		6·02		
			60,700		31·0	— 0·03
Fort Oglethorpe, .	11·4	260		5·91		

(6*b*) SAVANNAH RIVER AT HIGH RANGES.

Locality.	*Distance from Mouth. Nautical Miles.*	*S Millions Square Feet.*	*Mean A of Stretch. Square Feet.*	*R Feet.*	*Mean C of Stretch.*	*Change of Range per to Miles and per Foot of Range.*
Lower end Long Island, ...	4·6	407		7·71		
			62,950		25·5	— 0·11
Fort Oglethorpe, .	11·4	260		7·16		
Lower end Long Island, ...	4·6	407		8·89		
			64,750		23·2	— 0·17
Fort Oglethorpe, .	11·4	260		7·94		
(7) WESER.						
Bremerhafen, . .	0	641·4		10·8		
			88,100		22·2	— 0·10
Elsfleth, ...	18·5	180·0		9·0		
			19,600		32·0	— 1·15*
Vegesack, . . .	27·2	55·5		3·0		
			6,500		141·0	— 2·28*
Hasenbueren, . .	31·8	21·7		0·9		
Bremen, ...	37·3			0		
(8) SEINE.						
Le Havre, . . .	0					
La Risle, ...	10·8	484		14·50		
			36,150		9·7	— 0·33
La Malleraye, . .	34·0	293		6·40		
Duclair, ...	47·5	210·4		5·12		
			24,000		38·7	no change
Rouen, ...	66·4	81·3		5·22		
St. Aubain, . . .	80·4			3·21		
(9) NANSEMOND.						
Newman's Point,	0	129·5		3·01		
			14,300		129	+ 0·19
Suffolk, ...	12·1			3·78		
(10) JAMES RIVER.						
Mouth, ...	0	144·7		2·90		
			19,500		85·2	+ 0·10
Willis Wharf, . .	18·8	33·3		3·50		
			9,450		137·1	no change
Brewery, ...	27·9			3·50		

* Influence of upper slope perceptible


140
130
120
110
100
90
80
70
60
50
40
30
20
10
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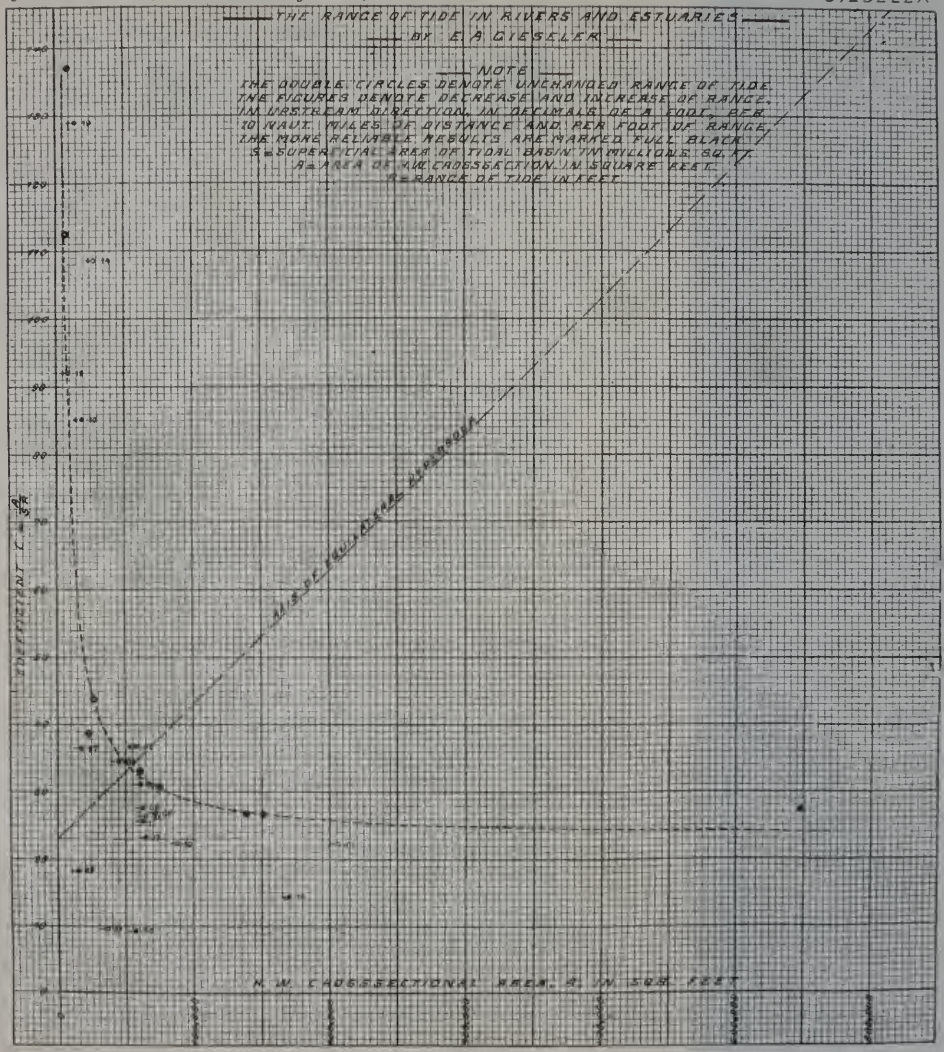
COEFFICIENT C = A/SR


THE RANGE OF TIDE IN RIVERS AND ESTUARIES
BY E. A. GIESELER
NOTE
THE DOUBLE CIRCLES DENOTE UNCHANGED RANGE OF TIDE.
THE FIGURES DENOTE DECREASE AND INCREASE OF RANGE
IN UPSTREAM DIRECTION, IN DECIMALS OF A FOOT, PER
10 NAUT. MILES OF DISTANCE AND PER FOOT OF RANGE.
THE MORE RELIABLE RESULTS ARE MARKED FULL BLACK.
S = SUPERFICIAL AREA OF TIDAL BASIN IN MILLIONS SQ. FT.
A = AREA OF M.W. CROSSSECTION IN SQUARE FEET.
R = RANGE OF TIDE IN FEET.
M.W. CROSSSECTIONAL AREA, A, IN 500 FEET

(11) ST. JOHN'S.

Locality.	*Distance from Mouth. Nautical Miles.*	*S Millions Square Feet.*	*Mean A of Stretch. Square Feet.*	*R Feet.*	*Mean C of Stretch.*	*Change of Range per 10 Miles and per Foot of Range.*
Mouth, ...	0			4·6		
Mayport Mills, . .	1·5	4172		4·3		
			57,500		9·3	— 0·68
Jacksonville, . . .	19·8	3540		1·0		
			130,000		31· (?)	
Black Point, . . .	26·2	3164				
			140,000		70 (?)	
San Patricio, . . .	41·9	2028				
			125,000		160 (?)	
Tocoi, ...	57·5	941				
			90,000		250 (?)	
Palatka, ...	73·2	237				
Georgetown, . . .	95·8					

The coëfficients of St. John's River above Jacksonville are approximate only, because *R* is not known; their rapid increase, however, cannot be doubted, and makes it probable that somewhere above Black Point an increase of range takes place.

NEW ALLOYS AND THEIR ENGINEERING APPLICATIONS.

BY F. LYNWOOD GARRISON.

[*A lecture delivered before the Franklin Institute, January 30, 1890, and February 6, 1891.*]

[*Continued from p. 65.*]

Aluminum Steel.—The effect of aluminum upon the properties of iron and steel is a subject upon which there is much difference of opinion amongst metallurgists. It will suffice, however, for our present purposes to merely call attention to a few fairly well-established facts on the subject. The use of ferro-aluminum and aluminum steel in the arts is quite new, and it can hardly be said we know much of their properties and peculiarities. According to the results of a series of experiments recently made by Mr. James Riley, at the works of the steel company of Scotland.*

* *Journal of the Iron and Steel Institute*, No. 1, 1890, p. 167.

It seems "that the addition of aluminum slightly increases the breaking strain, and proportionately the elastic limit in rolled and cast steel, according to the amount added, up to not more than one per cent., when further additions do no more good." (See Table 1.)

It also somewhat improves the extension in rolled steel, but after 0·5 per cent. is passed each addition of aluminum reduces extensibility. Its addition is useful, because of a greater fluidity of the steel, where castings of comparatively thin metal are to be run. On the other hand, contraction cracks are more liable to occur, unless the temperature of the castings be kept low.

Until quite recently, there seemed to be a general impression amongst metallurgists that the addition of aluminum, either the metal itself or in the form of a mixture of cast iron and aluminum (ferro-aluminum), to low carbon iron or to steel had the effect of lowering the fusing point of the metal. This statement has by no means been proved or disproved.

In February, 1886, at the meeting of the American Institute of Mining Engineers in Pittsburgh, Mr. Petter Ostberg, of Stockholm, Sweden, exhibited specimens of exceptionally good malleable iron (mitis) castings, which he claimed were produced from wrought iron or steel. He says, in his paper,* "We heat the wrought iron just to melting, but not more; and as soon as molten, we add from 0·05 to 0·1 per cent. aluminum, thereby producing a sudden lowering of the melting point." Recent investigations, however, have shown this statement to be open to question, as it is a well-known fact that ordinary steel sometimes contains small quantities of aluminum without having its melting point affected. Mr. Howe states that the most careful chemists have never succeeded in detecting aluminum in in these mitis castings.†

Analyses of Mitis, by Dr. Edward Riley, show as an average of seven samples: carbon, 0·099; silicon, 0·100; phos-

* *Trans. of the Am. Inst. of Mining Engineers*, vol. xiv, p. 777.

† Howe's *Metallurgy of Steel*, pp. 88, 130.

TESTS. *Hadfield.*

Series and Mark Referred to in Paper.	Carbon.	Silicon.	Sulphur.	Fracture ur.	Appearance of Fracture of Annealed Forged Bar from which Test Bar was Prepared.	Bending Tests of Annealed Forged Bars, 11-16 Inch Wide by ⅛ Inch Thick.	Welding Tests.
1167	·22	·09	—	dark; a smooth			
1167	—	—	—	a little oth on	Close fine granular.	Bent double cold.	
1167 A	·15	·18	·10				
1167 A	—	—	—	smooth	Close fine granular.	Bent double cold.	
1167 B	·20	·12	—	several y.			Would not weld.
1167 B	—	—	—	ough on	Fine close granular; much closer before annealing.	Bent double cold.	
1167 C	·18	·16	·09	several body.			
1167 C	—	—	—	ough on	Fine grain.	Bent double cold.	
1167 D	·17	·10	—				Would not weld.
1167 D	—	—	—	smooth	Fine close grain; much closer before annealing.	Bent double cold.	
1167 E	·26	·15	·08	ranular; tside.			
1167 E	—	—	—	smooth	Fine grain.	Bent double cold.	
1167 F	·21	·18	—	ough on			
1167 F	—	—	—	ough on	Coarser.	Bent double cold.	
1167 G	·21	·18	·09	er coarse.			Would not weld.
1167 G	—	—	—	fibrous; outside.	Coarser.	Bent double cold.	
1167 H	·24	·18	—	r circle, 20 per cle, finer rather			
1167 H	—	—	—	fibrous.	Coarser.	Bent double cold.	
1167 I	·22	·20	·08	ustrous; is.			
1167 I	—	—	—	ustrous; is.	Coarse.	16° Broken.	
1167 J	·26	·33	·08			Would not forge.	

ALUMINUM STEEL.

TABLE I.—TENSILE TESTS OF ANNEALED AND UNANNEALED BARS; ALSO SPECIFIC GRAVITY, FORGING, WELDING AND BENDING TESTS. *Hadfield.*

Series and Mark Referred to in Paper.	Analysis Per Cent. Carbon.	Silicon.	Sulphur.	Phosphorus.	Manganese.	Aluminum.	Calculated Percentage of Aluminum.	Loss (Approx.) Per Cent. of Aluminum.	Specific Gravity.	Drillings taken from.	How Ingot Forged.	Whether Tested in Annealed or Unannealed Condition	Original Diameter in Inches.	Original Area in Inches.	Limit of Elasticity in Tons per Sq. Inch.	Amount of Stretch in Inches at Elastic Limit.	Breaking Load in Tons per Square Inch on Original Area.	Extension Measured in a Length of — Inches.	Total Extension. Per Cent.	Reduction of Area. Per Cent.	Appearance of Fracture of Test Bar.	Appearance of Fracture of Annealed Forged Bar from Which Test Bar was Prepared.	Bending Tests of Annealed Forged Bars, 1 Inch Wide by ½ Inch Thick.	Welding Tests
1167	·22	·09	—	—	·07	·15	·25	·10	—	Ingot.	Very well	Unannealed.	·7979	·50	21·00	—	29·00	2	36·70	62·9	Granular; very dark, a little roaked; smooth on outside.			
1167	—	—	—	—	—	—	—	—	—	—	—	Annealed.	·7979	·50	20·0	—	25·00	2	41·30	63·82	Dark granular, a little roaked, smooth on outside.	Close fine granular.	Bent double cold.	
1167 A	·15	·18	·10	·04	·18	·38	·50	·12	—	Ingot	Fairly well.	Unannealed.	·7979	·50	23·0	—	30·0	2	37·85	58·18	Dark granular.			
1167 A	—	—	—	—	—	—	—	—	—	—	—	Annealed.	·7979	·50	20·0	—	26·0	2	40·35	60·74	Dark granular; smooth on outside.	Close fine granular.	Bent double cold.	
1167 B	·20	·12	—	—	·11	·61	·75	·14	7·781	Ingot	Rather shelly.	Unannealed.	·7979	·50	21·50	—	28·0	2	38·40	54·50	Dark granular; several specks in body.			Would not weld.
1167 B	—	—	—	—	—	—	—	—	—	—	—	Annealed.	·7979	·50	18·0	—	25·50	2	40·50	61·98	Dark granular, rough on outside.	Fine close granular; much closer before annealing	Bent double cold.	
1167 C	·18	·16	·09	·03	·14	·66	1·00	·34	—	Ingot	Very well.	Unannealed.	·7979	·50	20·50	—	29·0	2	33·35	49·86	Dark granular, several long specks in body.			
1167 C	—	—	—	—	—	—	—	—	—	—	—	Annealed.	·7979	·50	18·0	—	27·0	2	33·0	52·14	Dark granular; rough on outside.	Fine grain.	Bent double cold.	
1167 D	·17	·10	—	—	·18	·72	1·25	·53	7·755	Ingot	Very well.	Unannealed.	·7979	·50	22·0	—	28·0	2	40·0	60·74	Dark granular.			Would not weld.
1167 D	—	—	—	—	—	—	—	—	—	—	—	Annealed.	·7979	·50	18·0	—	25·0	2	47·10	64·86	Dark granular; smooth on outside.	Fine close grain; much closer before annealing.	Bent double cold.	
1167 E	·26	·15	·08	·04	·11	1·16	1·50	·34	—	Ingot.	Very well.	Unannealed.	·7979	·50	23·0	—	33·0	2	32·05	51·46	Dark fine granular; smooth on outside.			
1167 E	—	—	—	—	—	—	—	—	—	—	—	Annealed.	·7979	·50	21·0	—	29·0	2	34·40	53·02	Dark granular, smooth on outside.	Fine grain.	Bent double cold.	
1167 F	·21	·18	—	—	·18	1·60	2·00	·40	7·6237	Ingot	Rather shelly.	Unannealed	·7979	·50	20·0	—	31·0	2	32·70	52·14	Dark granular, rough on outside.			
1167 F	—	—	—	—	—	—	—	—	—	—	—	Annealed.	·7979	·50	13·0	—	26·0	2	36·35	67·06	Dark granular, rough on outside.	Coarser.	Bent double cold.	
1167 G	·21	·18	·09	·03	·18	2·20	2·50	·30	—	Ingot.	Fairly sound	Unannealed.	·7979	·50	21·0	·0080	31·0	2	22·75	27·80	Crystalline, rather coarse.			Would not weld.
1167 G	—	—	—	—	—	—	—	—	—	—	—	Annealed.	·7979	·50	19·0	·0095	28·0	2	34·87	47·12	Dark granular; fibrous; very rough on outside	Coarser.	Bent double cold.	
1167 H	·24	·18	—	—	·32	2·24	3·50	1·26	7·554	Ingot.	Fairly well	Unannealed.	·7979	·50	21·50	·0085	32·50	2	20·67	24·64	80 per cent. outer circle, crystalline; 20 per cent. inner circle, finer crystalline; rather coarse.			
1167 H	—	—	—	—	—	—	—	—	—	—	—	Annealed.	·7979	·50	18·50	·0133	28·50	2	33·02	48·62	Dark granular fibrous.	Coarser.	Bent double cold.	
1167 I	·22	·20	·08	·03	·22	5·60	6·00	·40	—	Ingot	Very shelly.	Unannealed.	·7979	·50	None visible.	—	38·0	2	3·67	3·96	Crystalline; lustrous, broke in radius.			
1167 I	—	—	—	—	—	—	—	—	—	—	—	Annealed.	·7979	·50	27·00	·0050	36·0	2	6·45	6·16	Crystalline; lustrous; broke in radius	Coarse.	16° Broken.	
1167 J	·26	·33	·08	·03	·25	9·14	10·00	·86	6·6726	Ingot.	Would not forge.	—	No test bar made; would not forge.										Would not forge.	

phorus, 0·153, and manganese, 0·022 per cent. No aluminum was found in this metal. It will be noticed that the above average of elements is about the same as the analysis of ordinary wrought iron with the slag removed. The silicon and manganese are a little high.* The fact is, the fluidity of this metal and its excellence for castings is, perhaps, as much due to the other elements present in the metal and to the peculiar method of melting it, as to the minute quantity of aluminum added.

Omitting from consideration the action of aluminum on cast iron, we find, according to Keep's researches, that the general effect of aluminum (or ferro-aluminum) when added to molten non-carburetted iron just before teeming, is quieting. This action is very marked, and is more sudden than that of ferro-silicon

While the addition of ferro-aluminum makes non-carburetted iron more fluid (but it does not necessarily follow the fusing point has been lowered), it does not seem to act in same way on steel with over 0·25 per cent. carbon. When the carbon point exceeds this it appears to decrease rather than increase the fluidity.

Without special additions, non-carburetted iron usually evolves gases so copiously in setting that its castings are porous. The action of the aluminum is probably to unite with and to remove the oxygen present in the steel in one form or another; as is especially the case with cold blown steel.

In summing up his work on aluminum in carbonized iron, Keep observes† that in whatever way the end is accomplished, aluminum seemed to permit good castings to be made from metal which could not be otherwise used alone. This remark applies more particularly to cast iron (carburetted) and to steel.

Keep also states,‡ that presence of 0·20 per cent. aluminum makes the grain of ingot iron (mild steel ?) close and uniform, removes blowholes, increases the ultimate strength

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* Keep, *Trans. of the Am. Inst. of Mining Engs.*, vol. xviii, p. 838.

† *Journal of the Iron and Steel Inst.*, No. 1, 1890, p. 132.

‡ *Trans. of the Am. Inst. of Mining Engineers*, vol. xviii, p. 835.

fifty per cent., but diminishes the viscosity or tendency to flow. Power to resist shock is almost doubled.

According to Mr. R. A. Hadfield,* it is doubtful whether aluminum increases the fluidity of properly-made steel, but if it does, the apparent increase or evolution of heat seems far more likely to account for any increase of fluidity that may occur rather than to the so-called lowering of the melting point.

As the aluminum increases to large amounts, say above ·50 per cent., the metal becomes quite thick, "creamy," and sets quickly. No doubt this is partly caused by a considerable portion of the aluminum being oxidized to alumina and becoming entangled as slag, in the same way as occurs when silicon is oxidized to silica. Unless suitable flux is present, this excess of oxide cannot be carried off, the molten metal becomes less fluid, and causes the "thickness" noticed. There is a resemblance in this respect to the action of high percentages of silicon added to iron. When exceeding about ·75 per cent. aluminum, the molten material so rapidly "creams over" on the surface, that the production of sand-moulded articles is only effected with difficulty; in fact, it was only by using considerable care that the cast test bars were obtained.† It must not be overlooked that Mr. Hadfield is here referring to comparatively high percentages. So far as his own experiments have gone, aluminum, as regards lower percentages, also acts in a similar manner to silicon under the same circumstances.

It does not appear from Hadfield's experiments that the addition of aluminum improves the soundness of castings any more than does silicon, manganese, or silicon combined with manganese. It seems, however, that more aluminum may be present in cast material than silicon in cast silicon-steel before brittleness sets in.

After reaching the region of brittleness, and by adding still higher percentages of aluminum, there is no return of

* *Journal of the Iron and Steel Inst.*, No. II, 1890, p. 171

† Mr. Keep, even with cast iron, found a decided decrease in fluidity by the addition of aluminum.

strength—on the contrary; so that this material in no way resembles the curious properly noted in this respect with regard to manganese steel.

The gradual increase of aluminum is very clearly shown to reduce the toughness both of unannealed and annealed specimens.

As might be expected from the soft nature of the metal aluminum, its addition to iron does not add materially to the hardness, again in this respect resembling the effect of silicon. Seven to eight per cent. cast aluminum steel may be readily drilled and filed.

Hadfield considers that the action of aluminum may be classed along with that of silicon, sulphur, phosphorus, arsenic and copper, as giving no increase of hardness to iron, in contradistinction to carbon, manganese, chromium, tungsten and nickel. Water-quenching upon either forged or cast aluminum steel seems to produce no effect.

Here again we have another addition to the list of elements which, alloyed with iron, do not produce "water-quenched hardness," if the term may be allowed. In fact, notwithstanding that manganese, chromium, tungsten and nickel do impart a certain and considerable kind of hardness to iron, either in the cast or forged state, carbon retains its position as being the only element which confers upon iron the property of becoming hard by water-quenching. In steel, made with the hard metals just mentioned, if the carbon present be low, no matter at what heat they are water-quenched, the characteristic hardness of carbon steel, such as scratching glass or forming the edge of a cutting tool, is wanting.*

As regards malleability, as much as 5·60 per cent. aluminum may be present in the steel before malleability ceases. This is about the same limit as in the silicon steel described by Hadfield.

Comparing (Table I) the sample of aluminum steel containing 1·6 per cent. aluminum and ·12 per cent. carbon, with silicon steel of 1·60 per cent. silicon and ·19 per cent.

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* Hadfield, *Jour. Iron and Steel Inst.*, No. II, 1890, p. 180.

carbon,* the former has an advantage in elongation of one per cent. A characteristic of the aluminum steel is that the reduction in area is greater; in this respect it seems to resemble chrome steel. There is, however, considerable difference in the tensile strength of the two alloys, the aluminum steel being several tons less. The same remark applies to the permanent set point, which in the annealed aluminum steels is fairly low. Numerous comparisons might be drawn between the two steels, especially as the test bars in both series of experiments were exactly the same in length and section, and were treated on all points similarly. Reference to the diagrams and tables in each case will be found of interest. One difference clearly brought out is, that the tensile strength of iron is not increased so much by an addition of aluminum as of silicon.

It has been stated that very small percentages of aluminum considerably raise the limit of elasticity. It will be seen from the table of tests, and specially from the two almost carbonless samples, just quoted, that this increase is slight, if any, as compared with ordinary steel, and also that aluminum does not raise the elastic limit so much as silicon.†

Aluminum causes the tough percentages, both in the cast and forged material, to break with dark fibrous fracture, similar to wrought iron of good quality, only much darker in color. This appearance in some of the specimens is very curious, as small patches of bright fine crystals are to be seen surrounded by a remainder of black and dark fibrous material.‡

Hadfield has always found that these special steels or alloys, such as silicon, manganese or chromium steel have but slight, if any, welding properties.

Speaking generally of the application of aluminum to the manufacture of iron and steel, the usual amount stated to be requisite for producing good results is about ·10 per cent.; but in many cases this would be too little.

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* See table under silicon steel.

† Hadfield, *Jour. Iron and Steel Inst.*, No. II, 1890, p. 178.

‡ *Ibid.*, p. 180.

The chief obstacle to the extensive use of aluminum in this particular is its comparatively high cost. If aluminum can eventually be brought to compete in price with existing alloys, it may find use for certain special purposes such as in higher carbon-steel where, according to Hadfield, silicon does not seem to act so powerfully in producing soundness, as in the case of milder steel with carbon ·50 per cent. and under.

Therefore, whilst for some special purposes aluminum may be employed in the manufacture of iron, at any rate with our present knowledge of its properties, this use cannot be large, especially when taking into consideration the fact of its comparatively high price. Its special advantage seems to be that it combines in itself the advantages of both silicon and manganese; but so long as alloys containing these metals are so cheap and aluminum dear, its extensive use seems hardly probable.*

Chrome Steel.—Chromium increases the hardness of iron, perhaps also the tensile strength and elastic limit, but it lessens its weldibility.

Ferro-chrome, according to Berthier,* is made by strongly heating the mixed oxides of iron and chromium in brasqued crucibles, adding powdered charcoal if the oxide of chromium is in excess, and fluxes to scorify the earthy matter and prevent oxidation.

This, according to Howe,† is substantially the method employed at Brooklyn, N. Y., and at the Unieux Works in France, where chrome steel has been produced in large amounts for a number of years. Chrome steel is easily made from ferro-chrome by simply melting it with wrought iron or steel in graphite crucibles.

Up to the present time the best available data regarding chrome steel are rather contradictory. In this as in all the other steel alloys, the physical properties vary greatly, according to the relative proportions of the other elements present in the alloy.

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* Hadfield, *Jour. Iron and Steel Inst.*, No. II, 1890, p. 181.

* *Annales des Mines*, 1st ser., vi., p. 573.

† *Metallurgy of Steel*, p. 75.

In general, it may be considered that chromium has the tendency to harden steel. This, however, is by no means a general rule, as this hardening property may in great degree depend upon the relations and proportions of the other elements present.

In most cases chromium increases somewhat the tensile strength and elastic limit of steel. Its ductility, according to Howe,* when subjected to elongation, is not necessarily increased. Mr. Howe also states the same is true when the alloy is subjected to shock. The Holtzer Company (Unieux, France,) have, however, for a number of years been making remarkably hard and tough projectiles with chrome steel.

It is said unhardened chrome steels are somewhat harder and more difficult to cut than chromeless steels of like carbon content,† and their hardness increases with the percentage of chromium.

Chromium does not appear to give steel the power of becoming harder when quenched or chilled.

Howe‡ states that chrome steels forge more readily than tungsten steels, and when not containing over 0·5 of chromium nearly as well as ordinary carbon steels of like percentage of carbon.

Chrome steel is not easily welded, owing to the difficulty of scorifying off the scale of oxide. This difficulty probably increases with the content of chromium. Chrome steel has the great advantage of cheapness, and for steel projectiles and some special purposes has given some excellent results.

On the whole, however, the status of chrome steel is not satisfactory. There are other steel alloys coming into use, which are so much better, that it would seem to be only a question of time when it will drop entirely out of the race.

Howe§ states that many experienced chemists have found no chromium, or but the merest traces, in chrome

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* *Metallurgy of Steel*, p. 77.

† *Ibid.*, p. 77.

‡ *Ibid.*, p. 78.

§ *Ibid.*, p. 79.

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TABLE II.—CHROME STEEL. *Howe.*

Number	Observer, Source, etc.	Composition. Chromium.	Combined Carbon	Graphite.	Manganese.	Silicon.	Tungsten.	Physical Properties. Tensile Strength. Pounds per Square Inch.	Elastic Limit. Pounds per Square Inch	Elongation. Per Cent	Elongation. Inch.	Reduction of Area Per Cent	Bent Before Breaking. Degrees.	Diameter of Piece. Inches
1	Unieux, unhardened, Brustlein,	4	1 10	—	—	—	—	177,800	177,000 ±	7 5	—	—	—	—
1*5	Faraday and Stodart, very hard, extremely malleable,	2·9 ±	1 ?	—	—	—	—	—	—	—	—	—	—	—
2	Unieux, unhardened, } same steel,	2·2	0·6	—	—	—	—	103,000	67,500	19·	—	67 +	—	—
3	" annealed after oil hardening. } Brustlein,	2·2	0 6	—	—	—	—	199,000	199,000	3·	—	—	—	—
4	" Brustlein,	1·2	34	—	—	—	—	88,180	53,300	7	—	—	—	—
4*5	Faraday and Stodart, hard, forged well,	·99 ±	1·?	—	—	—	—	—	—	—	—	—	—	—
5	A. A Blair and D Smith, P,	·45 @ ·92	·84 @ 1·19	·01 @ ·03	·03	1·28	—	115 922	—	—	—	—	—	—
6	" " F,	·22 @ ·64	·81 @ ·99	·01 @ ·02	—	—	—	104,755	—	—	—	—	—	—
7	Brooklyn Adamantine, Hunt and Clapp and the author,	·53	1·03	—	17	·05	—	{ 157,600 *a* { 116,600 *b*	— —	0·6 ·76	4" 4"	— 0·	2·5 15·5	·53 octag 53 "
8	Döhlen, Ledebur,	·50	·91	—	—	—	—	122,300	—	15·7	—	—	—	—
9	Brooklyn very hard, Hunt and Clapp and the author,	38	·90	—	1 69	·03	·38	134,600	—	2	4"	0·	4·	43 octagon
9*5	A A. Blair and D Smith, G,	38	·84	·01	2	·69	—	111,572	—	—	—	—	—	—
10	Brooklyn, St. Louis Bridge (?) Blair,	38	·94	—	—	—	—	—	—	—	—	—	—	—
11	" " " (?) "	36	·98	—	—	—	—	—	—	—	—	—	—	—
12	" Hunt and Clapp and the author,	·29	1·32	—	15	·15	73	{ 124,000 *a* { 127,000 *b*	— —	6· 9·	3.5" 3·5"	4· 2·	1·5 5 5	63 rounds 63 "
13	" 1A, " " " "	·25	70	—	—	—	—	145,400	—	5·5	—	19	{ 25· *a* { 30· *c*	— —
14	" St Louis Bridge (?) Blair,	"	·60	—	—	—	—	—	—	—	—	—	—	—
15	" " " (?) "	·0	31	—	—	—	—	—	—	—	—	—	—	—
16	Unieux, unhardened,	—	—	—	—	—	—	108,700	85,446	15·	—	50·	60	86 octagon.
17	" quenched from yellow, } same bar, Barbier,	—	—	—	—	—	—	131,000	—	1 2	—	4·	—	—
18	" " " bright cherry, } Boussingault,	—	—	—	—	—	—	202,900	—	2	—	6	—	—
19	" " " cherry, }	—	—	—	—	—	—	104,260	62,306	14·	—	63·	—	—
20	" " " dark red, }	—	—	—	—	—	—	100,000	55,000	17·	—	63·	—	—
21	Brooklyn, West Point test, strongest bar,	—	—	—	—	—	—	187,915	—	—	—	—	—	—
22	" " weakest "	—	—	—	—	—	—	168,765	—	—	—	—	—	—
23	" Kirkaldy's test,	—	—	—	—	—	—	160,560	87,000	7·6	—	30·	—	—
24	" "	—	—	—	—	—	—	129,800	71,000	6·2	—	59·	—	—
25	" "	—	—	—	—	—	—	126,870	63,000	7 2	—	59	—	—
26	" "	—	—	—	—	—	—	124,300	54,000	11	—	47	—	—
27	Unieux, private communication,	—	—	—	—	—	—	157,600	—	—	—	57·	—	—
28	" " "	—	—	—	—	—	—	152,200	—	—	—	57·	—	—
29	" annealed, } same bar,	—	·7 ±	—	—	—	—	102,300	59,300	19·5	3"	68·	—	—
30	" oil hardened and annealed, } Brustlein,	—	·7 ±	—	—	—	—	213,300	199,000	6·2	3"	29·2	—	—
31	Brooklyn, Thurston,	1·04	·63	·01	·05	·15	—	—	—	—	—	—	—	—
32	" "	·92	44	·01	·02	·14	—	—	—	—	—	—	—	—
33	" "	·61	46	0	·03	·12	—	—	—	—	—	—	—	—

1 Unhardened, Unieux 1·5. Faraday and Stodart Forged well, with no disposition to crack hard, as malleable as pure iron, gave a very fine damask The composition here given is inferred from their statements that they melted together 1,600 grs. of steel, whose carbon is roughly assumed at 1 per cent., and 48 grs. of pure chromiom, and further that "in all the experiments made in the laboratory the button produced was weighed, and if it fell short of the weight of both metals put into the crucible it was rejected as imperfect." *Phil. Trans. Royal Soc.*, 1822, pp. 267, 258. 2 and 3. Unieux, 2 unhardened, 3 the same steel annealed from bright redness after oil-hardening. 4. Unieux. 4·5, Faraday and Stodart, *loc. cit.* good, forged well, with no disposition to crack hard, but not so hard as No. 1·5. The remarks concerning No 1·5 apply to No. 4·5. *mutatis mutandis.* 5 and 6. *Rept. of U. S. Bd. to Test Iron*, etc., II, p. 590. Thurston, *Mat'ls of Engineering*, II, p 424 7. Brooklyn "Adamantine" chrome steel, *a*, unhardened, *b*, quenched in oil from dull redness. Hunt and Clapp and Howe 8. Döhlen, *Ledebur, Handbuch*, p, 261 9. One of the hardest brands of Brooklyn chrome steel, Hunt and Clapp and Howe. 9 5. *Rept. U. S. to Test Iron*, II, p 590. 10 and 11 A A. Blair Said to be from struts of St. Louis Bridge: private communication. Mr. Howe, May 30, 1887. 12 and 13 Brooklyn chrome steel Hunt and Clapp and Howe 13 is styled "No 1A." *a*, Unhardened: *b*, hardened in oil from dull redness. 14 and 15. Brooklyn (?) chrome steel, said to be from struts of St Louis Bridge. A A Blair, private communication, May 30, 1887. 16 to 20. Unieux 16, hardened; 17, quenched from yellow; 18, from bright cherry. 19, from cherry; 20, from dark red (sombre). 21 strongest, and 22 weakest of three bars of Brooklyn chrome steel tested at West Point foundry. No. 21, in two trials, gave 176,920 and 198,910 pounds and after being heated, 168,530 and 193,210 pounds tensile strength, No. 22, in the same way, gave before heating 173,770 and 163,760 pounds and after heating 174,540 and 190,010 pounds, tensile strength per square inch 23 to 26. Kirkaldy, circular of Brooklyn Chrome Steel Co. 27, 28 Unieux Private communication from J. Holtzer et Cie. 29, 30. Unieux. 29, annealed. 30, oil-quenched, and annealed from dark redness. 31 to 33. Brooklyn, Thurston, *Mat'ls of Engineering*. II, p 307

UNIEUX STEELS.—Excepting Nos. 27, 28, and 31 to 33, described by Brustlein and Boussingault, *Ann de Chim et Phys*, 5th Ser., XV, and *Jour Iron and St Inst*, 1886, II, p 807.

BROOKLYN CHROME STEELS.—Nos 7, 9, 12 and 13, obtained by Howe from the makers or their Boston agents, and tested by him In the bending tests, these steels were held firmly in a vise and struck with moderate force with a sledge till they broke. The bending was measured after fracture.

a As received from the makers *b* After quenching in oil from dull redness *c* After annealing from cherry redness

TABLE III.—PHYSICAL PROPERTIES OF CHROME STEEL AND TUNGSTO-CHROME STEEL. *Holtzer and others.*

Number.	Tensile Strength. Pounds per Sq. In.			Elastic Limit. Pounds per Square Inch.			Elongation. Per Cent. in 7·9 Inches.			Contraction of Area. Per Cent.		
	Natural State.	Oil-hardened and Tempered	Oil-hardened and Annealed.	Natural State.	Oil-hardened and Tempered	Oil-hardened and Annealed.	Natural State.	Oil-hardened and Tempered	Oil-hardened and Annealed.	Natural State.	Oil-hardened and Tempered	Oil-hardened and Annealed.
1	156,877	—	—	—	—	—	9·5	—	—	54·5	—	—
	—	199,017	—	—	152,184	—	—	8	—	—	43	—
	—	—	104,538	—	—	63,575	—	—	19·5	—	—	63
2	109,230	—	—	64,571	—	—	18·3	—	—	59	—	—
	—	195,421	—	—	—	—	—	6	—	—	30·5	—
	—	—	136,112	—	—	118,760	—	—	13	—	—	58·1
3	93,443	—	—	55,753	—	—	22·5	—	—	38·5	—	—
	—	212,772	—	—	—	—	—	0·5	—	—	0	—
	—	—	124,592	—	—	109,230	—	—	6	—	—	17·5
4	94,439	—	—	55,753	—	—	26·5	—	—	50·5	—	—
	—	172,949	—	—	159,580	—	—	6·5	—	—	26	—
	—	—	122,600	—	—	106,386	—	—	12·2	—	—	30
5	95,292	—	—	56,749	—	—	20·8	—	—	30	—	—
	—	204,096	—	—	190,017	—	—	2·5	—	—	6	—
	—	—	116,769	—	—	104,538	—	—	7	—	—	33
6	103,115	—	—	65,425	—	—	17·5	—	—	33	—	—
	—	212,772	—	—	193,430	—	—	1·8	—	—	7	—
	—	—	137,107	—	—	123,596	—	—	6·2	—	—	15
7	114,635	—	—	72,251	—	—	14·5	—	—	24	—	—
	—	210,497	—	—	189,163	—	—	—	—	—	—	—
	—	—	148,201	—	—	133,409	—	—	5	—	—	13
8	142,000 @ 156,000			113,800 @ 128,000			10 @ 12 per cent. in 3·9 inches.			42 @ 45		
9	114,000			68,300			13·5*a*			—		
10	128,000 @ 142,000			—			9 @ 10*a*			—		

The "natural state" pieces are simply cooled slowly after forging.

The "oil-hardened and tempered" pieces are quenched in oil from a low yellow heat and slightly reheated.

The "oil-hardened and annealed" pieces are similarly quenched, reheated to very dull redness and cooled slowly.

Nos. 1 to 6 are chrome steels. Nos. 5, 6 and 7 contain both chromium and tungsten. 1 to 8, inclusive, are Holtzer's; 8 is for plates 0·59-inch thick, for the French navy. 9. Railway tire which has resisted 14 blows of a 1-ton ram falling 32 feet 10 inches. St. Chamond. 10. St. Etienne; usual properties of their armor plates 0·16 to 1·18-inch thick.

steel sold in the American and possibly British markets. Considerable amounts of chrome and tungsto-chrome steels are made in France by Holtzer, the St. Etienne and other steel works.

There was a rather extensive exhibit of chrome steel at the Paris Exhibition of 1889. The Holtzer Company (Unieux) use large quantities of it in making thin plates for cuirasses. Some of these thin plates, 0·16-inch thick, hardened and annealed, can then be bent double and hammered close. At the same time it is specified that they must not be penetrated by a lead rifle ball with a velocity of 1,500 feet per second, at a distance of thirty-three feet.*

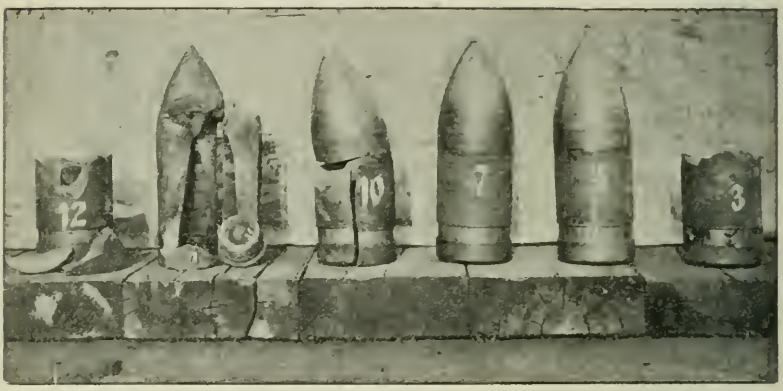

FIG. 5.

It has been stated that the presence of chromium in steel renders it more susceptible to oxidation by exposure to air and moisture than ordinary steel, and that this effect is quite the reverse of the action of tungsten.†

In *Fig. 5* we have shown some of the six-inch Holtzer chrome-steel projectiles (shells) which were used at the now celebrated armor-plate trials at Annapolis, Md., September 18, 1890. Four of these projectiles completely perforated the "compound" plate and lodged in the backing. Two of

* Howe, *Metallurgy of Steel*, p. 367.

† I do not know who is the author of this statement. I have never seen any evidence either to prove or disprove it.

them broke in half on the "nickel-steel" plate, the points sticking in the plate; two others remained in the plate apparently intact. One projectile remained in the "steel" plate, and two penetrated about twelve inches and rebounded entire, another did the same but broke into several pieces.

In *Fig. 6* we have shown the three-eighths inch "Firth armor-piercing shell" used in the same trials.* The first fired against the "nickel-steel" plate broke into fragments; the second completely penetrated the "compound" plate and was recovered entire; the third broke into three large pieces on the "steel" plate.†

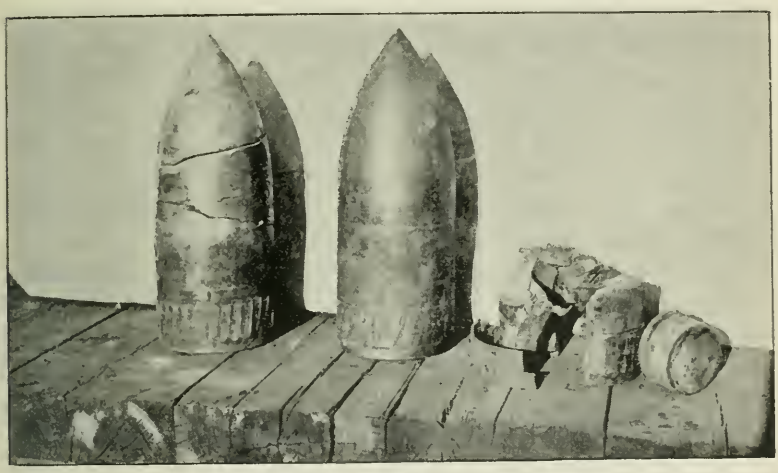

FIG. 6

Copper Steel.—A few years ago M. Henri Schneider, of Creusot, France, took out patents for the manufacture of alloys of iron and copper, and steel and copper. In the patent specifications it is stated the alloy of cast iron and copper can be made in a crucible, cupola, or open-hearth furnace. "The furnace is charged with copper scrap and

* The Firth shells are made by what is termed the Firminy process, which appears to be a secret method of chilling and tempering chrome and tungsten steel projectiles.

† These photographs, and also a number of others of the armor plate, I have received through the courtesy of the Navy Department.

cast iron mixed between layers of coke, or if a cupreous coke be employed then the cast iron is laid in alternate layers with it, and a layer of anthracite is preferably laid over the whole. The alloy thus formed contains, generally, from five to twenty per cent. of copper, according to the purpose for which it is to be employed, and it is remarkable for its great strength, tenacity and malleability—properties which may be still further developed by chilling or tempering."*

The alloy thus formed is charged into the bed of a furnace, with the ordinary ingredients used in the manufacture of steel, preferably under a layer of anthracite, to avoid oxidation. It is important that the copper be introduced at as early a stage in the process as possible. The said alloy may be introduced either while molten or in its hardened condition, or it may be prepared in the furnace itself, where the operation of manufacturing the steel is carried on. In the latter case, the bed of anthracite is first prepared and the copper placed thereon with a suitable quantity of cast or pig iron. The whole is then covered with anthracite, in order to protect the metal from contact with the air during fusion. When the charge is melted, the excess of anthracite is removed and successive charges of iron or scrap added, the operation being then continued in the ordinary way, care being taken to continually protect the bath from oxidation by means of a layer of slag or cinder, which may be renewed as required, and also to prevent red-shortness in the metal before the final introduction of the recarbonizing and manganiferous silico-spiegel iron or ferro-manganese.

The steel produced by this means contains from two to four per cent. of copper.

It is stated in the patent specifications that the steels alloyed with copper are especially useful in the manufacture of ordnance, armor-plate, gun-barrels, projectiles and other military purposes, or in the manufacture of commercial bars, sheets, etc.†

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* U. S. Patent 415,656, Nov. 19, 1889.

† U. S. Patent 415,654, Nov. 19, 1889. The British Patents Nos. 16,568 and 16,569, 1888, seem to have been abandoned in 1890.

The presence of copper in steel was formerly regarded as injurious, tending to cause a red-shortness and a sensible diminution of its tenacity. As a matter of fact, such is generally the case except under certain conditions when its presence seems to be an absolute benefit.

Small amounts of copper (under five per cent.) readily alloy with steel. It is very doubtful if steel will form a perfect alloy with over ten per cent. of copper. Mushet found that although five per cent. of copper formed an apparently homogeneous alloy with steel, when the copper reached ten per cent. minute segregation appeared. When twenty-five per cent. of copper is present, much of it sinks to the bottom of the molten alloy and is found, on cooling, in patches and streaks; with white cast iron, this tendency to segregate is even stronger. It is probably accounted for by the fact that the presence of carbon tends to diminish the union of iron and copper.

Mr. James Riley, of Glasgow, has recorded a very interesting observation on the presence of copper in steel.* "If an alloy of steel and copper be made, and the resultant metal were examined under the microscope, it would be found the copper was not alloyed—it was disseminated all through the piece. If, in making that alloy they used some aluminum, they would find a totally different result—the alloy was perfect."

Copper acts much like sulphur in rendering steel more or less red-short and destroying its welding power. Whether the presence of manganese counteracts this effect of copper like it does that of sulphur is not yet known.†

Mr. Willis, of the Landore Works, in South Wales, found that 0·1 per cent. of copper produced no appreciable effect on the quality of the steel.‡ Wasum § has shown that an appreciable amount of copper may be present in steel without affecting its quality, so long as there was no notable

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* *Journal of the Iron and Steel Institute*, No. 1, 1890, p. 123.

† Howe's *Metallurgy of Steel*, p. 83.

‡ *Iron*, Vol. 28, p. 539.

§ *Stahl und Eisen*, 1882, p. 193.

amount of sulphur present. According to Choubly* steel of the following composition rolled perfectly well: Carbon, 0·5; phosphorus, 0·15; sulphur, 0·04, and copper, 1·0 per cent.

Ball and Wingham, in their researches on the influence of copper on the tensile strength of steel, give the following as some of their results:†

Test-Piece No.	*Copper. Per Cent.*	*Carbon. Per Cent.*	*Tensile Strength. Pounds per Sq. In.*	*Elongation. Per Cent.*
1, ...	0·847	0·102	40,992	10
2, ...	2·124	0·217	81,984	5
3, ...	3·630	0·380	106,624	5
4, ...	7·171	0·712	125,440	nil

The following tests are of some copper steels exhibited at the Paris Exhibition of 1889, by Messrs. Holtzer, of the Unieux Steel Works.‡ They contained from three to four per cent. of copper.

The exceedingly high elastic limit of the hardened bars should be noted; it is almost equal to the tensile strength, at the same time the elongation is considerable.

No.	*Elastic Limit. Pounds per Sq. In.*	*Tensile Strength. Pounds per Sq. In.*	*Elongation. Per Cent.*
1, ...	43,563	77,761	22·5
2, ...	99,330	109,972	17·5
3, ...	94,789	113,236	13·0
4, ...	65,274	83,721	18·6
5, ...	141,900	173,543	6·2
6, ...	121,324	149,420	11·0
7, ...	94,789	121,324	14·5
8, ...	—	156,090	2·0

1 and 4. Natural state.
3, 5 and 8. Oil hardened and tempered.
2, 6 and 7. Oil hardened and annealed.

According to Brustlein, copper steels with more than one per cent. of copper are decidedly red-short; he believes such steels have no future; that copper does not appear to be uniformly distributed through the metal, and that it

* *Bulletin de la Société de l'Industries Minerale*, xiii, 205.

† *Journal of the Iron and Steel Institute*, No. 1, 1889, p. 125. *Journal of the Franklin Institute*, July, 1890, p. 35.

‡ *Journal of the Franklin Institute*, August, 1890, pp. 123, 124.

appears to favor the formation of blowholes.* It has been thought that the red-shortness which usually accompanies the presence of copper is due rather to the formation of sulphide of copper—the copper taking up sulphur from the furnace gases—than to the copper itself.†

W. W. Scranton, of the Scranton Steel Works, habitually makes Bessemer T-rails with 0·51 to 0·66 per cent. copper; he states they are non-redshort.‡

Copper-steel alloys are almost too new to determine for what particular purposes they would be most useful. It is stated in the Schneider patents that they are useful for making ordnance, armor plate, rifle barrels and projectiles and also for girders for building purposes and ship plates.

In view of the remarkable elastic limit of copper steel while maintaining at the same time a very considerable elongation, it would not be surprising if its use became very extensive in the arts. It has the advantage of aluminum, nickel and tungsten steels in being cheaper to manufacture. In many of the steel alloys, the alloying metals have to be added to the steel when they are combined with iron, which iron must necessarily contain some carbon—such an increase of carbon in the alloy is nearly always undesirable. Thus, for instance, if the manganese in manganese steel could be added as metallic manganese and not as ferro-manganese (which must contain carbon), we would probably obtain better results with manganese steel.

The undesirable increase of carbon in this way is avoided in making copper steel, for as we have seen, the copper can be added in the metallic state, or as an ore.

Messrs. Ball and Wingham in making their iron copper alloys took advantage of the reducing action of the carbon sulphur and silicon present in the pig iron.§

"The iron, rich in copper, was produced by melting pig iron, and then adding to the molten metal oxide of copper.

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* Howe's *Metallurgy of Steel*, p. 368.

† *Ibid.*, p. 369.

‡ *Ibid.*, p. 83.

§ *Journal of the Iron and Steel Inst.*, No. 1, 1889, p. 124. *Journal of the Franklin Inst.*, July, 1890, p. 35.

The carbon and silicon acted as the reducing agents for the cupric oxide, and the copper was thus introduced into the iron by a 'reaction,' and not by simple solution. A part of the other impurities in the pig iron was also burnt out in this manner, and a metal (A) was obtained which had the following composition:

METAL A.

	Per Cent.
Copper,	7 550
Carbon,	2·720
Manganese,	·290
Silicon,	·036
Phosphorus,	·130
Sulphur,	·190

"This metal was bright, white in color, crystalline, and very hard, but it did not offer any great resistance to impact. Varying quantities of it were then melted down with the basic Bessemer steel previously mentioned.

"The opportunity afforded by the preparation of the metal A was taken for observing the order in which the carbon, sulphur and silicon originally present in the pig iron were eliminated by the oxygen of the cupric oxide added, the percentage of sulphur in the metal having been largely increased for the purpose of this experiment, which consisted in melting the iron in a graphite crucible, and then making successive additions to it of cupric oxide. After each addition of the oxide, the metal was poured, a sample taken for analysis, and the remainder charged into the crucible again and remelted, a further addition of cupric oxide being then made.

"The following table shows the composition of the pig iron used, as well as that of the samples taken after each successive addition of cupric oxide:

Description.	*Silicon. Per Cent.*	*Carbon. Per Cent.*	*Sulphur. Per Cent.*
Pig iron,	1·02	2·60	1·44
First sample,	0·55	2·32	1·27
Second sample,	0·10	2·02	1·12
Third sample,	0·05	1·77	1·18
Fourth sample,	trace	0·61	1·08
Fifth sample,	trace	0·34	0·85

"It will be observed that whilst the silicon was rapidly

oxidized, the carbon was only appreciably attacked after nearly the whole of the silicon had been eliminated; and, further, that the percentage of sulphur was not greatly affected till most of the carbon had been burnt off. This diminution in the percentage of sulphur may, however, to some extent be accounted for by the dilution of the pig iron by the copper reduced from the cupric oxide."

Manganese Steel.—The effect of small amounts of manganese on the strength and ductility of steel appears to be slight. Beginning, however, with about 2·5 per cent., a further increase of manganese diminishes both the strength and ductility, while conferring remarkable hardness. This effect reaches a maximum when the manganese is about five to six per cent., with a further increase the strength and toughness improves while the hardness somewhat diminishes. The maximum of both strength and toughness is probably reached with about fifteen per cent. manganese, the hardness still remaining so great that the metal can scarcely be machined. As the manganese rises above fifteen per cent. the ductility falls abruptly, while the tensile strength remains nearly constant until the manganese passes twenty per cent., when it in turn falls rapidly. Hadfield states that the best composition is that of fourteen per cent. manganese and not over one per cent. carbon. Such a metal is very fluid, solidifies rapidly and with great contraction, does not form blowholes, but pipes deeply, is forgeable, but welds poorly.*

The effect of this high percentage of manganese is obscured by the accompanying carbon, which rises unavoidably with the manganese. Even when containing as much as 21·67 per cent. manganese and 2·1 per cent. of carbon, manganese steel can be forged.

The chief obstacle to the commercial introduction of manganese steel is its hardness. The machining and tooling of some of the grades of this material is almost impossible by the ordinary methods.

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* R. A. Hadfield, on "Manganese Steel," *Journal of the Iron and Steel Institute*, No. 2, 1888.

Manganese steel is not so liable to contain honey-combs as the ordinary steel, and the addition of silicon to obviate unsoundness, is not necessary. It is very fluid, can be run in thin sections, but cools more rapidly than ordinary steel, with a decidedly greater contraction. Manganese steel, containing from four to six and one-half per cent. manganese, even if it has only 0·37 per cent. of carbon, can be powdered under a hand hammer. This grade is extremely ductile when hot. With eleven per cent. of manganese the metal, after heat treatment, has an elongation of twenty-two per cent., and a tensile strength of 110,000 pounds per square inch, while, with about fourteen per cent. of manganese we have fifty-one per cent. elongation in eight inches, and a tensile strength of 145,000 pounds per square inch.* Both castings and forgings are strengthened and toughened by heating to a yellow, or better, to a white heat, especially if suddenly cooled.

The effect of heat treatment on the tensile strength and ductility of forgings is very marked in the case of steel containing about twelve to fifteen per cent of manganese.† Within these limits, reheating manganese steel forgings to whiteness with slow cooling usually increases the strength and ductility to a marked degree; while if quenched instead of slowly cooled, the increase of strength and ductility is even more marked, the tensile strength being sometimes nearly doubled and the elongation jumping from two to forty-four per cent. in some cases. Indeed, it seems quite necessary to quench manganese steel rapidly in order to give it any considerable value. Fortunately, pieces of moderate size do not crack on quenching; but in attempting to quench large pieces, such as armor plates, in which stresses would naturally be much greater than in small ones, cracks are very apt to develop. Heating and quenching, instead of increasing seems rather to lower the elastic limit, already unfortunately low, and it is possible that it may thus injure rather than benefit the metal for many important purposes.

* Howe's *Metallurgy of Steel*, p. 362.

† *Ibid.*, p. 362.

MANGANESE STEEL, FORGED. *Hadfield.*

Numbers.	Composition					In the "Natural State"			Air-toughened.		Oil-toughened		Water-toughened		
	C.	Si	Mn	P	S.	Tensile Strength Pounds per Sq Inch	Elongation, Per Cent in 8 Inches	Contraction of Area Per Cent	Tensile Strength Pounds per Sq Inch.	Elongation, Per Cent in 8 Inches	Tensile Strength. Pounds per Sq Inch.	Elongation Per Cent in 8 Inches	Tensile Strength. Pounds per Sq Inch.	Elongation, Per Cent. in 8 Inches.	Contraction of Area Per Cent
1,	·20	·03	·83	·02	·06	7[illegible],920	31	46	—	—	—	—	—	—	—
2,	4[illegible]	·15	2·30	·03	·06	12[illegible],140	6	7	—	—	—	—	—	—	—
3,	·4[illegible]	·03	3·89	·02	·06	84,120	1	—	—	—	—	—	—	—	—
4,	·52	·37	6·95	·02	·06	56,920	2	—	47,[illegible]40	2	42,5[illegible]	1	51,520	2	—
5,	·47	·44	7·22	·02	·06	62,4[illegible]	2	—	6[illegible],480	5	56,[illegible]00	3	56,[illegible]00	2	—
6,	—	—	7·50	·02	·06	87,3[illegible]	4	9	—	—	—	—	—	—	—
7,	·50	·28	7·90	·02	·06	—	—	—	62,7[illegible]	8	67,[illegible]20	7	—	—	—
8,	1·00	·42	9·15	·02	·06	—	—	—	—	—	[illegible]4,[illegible]	17	—	—	—
9,	—	—	9·20	·02	·06	89,600	6	1[illegible]	—	—	—	—	—	—	—
10,	·61	·30	9·37	·02	·06	73,920	5	—	85,120	16	85,120	15	7[illegible],360	15	—
11,	·95	·21	10·11	·02	·06	85,120	5	—	83,[illegible]0	14	91,84[illegible]	20	—	—	—
12,	·85	·28	11·60	·02	·06	76,160	4	—	91,840	17	94,[illegible]	19	89,600	17	—
13,	—	—	—	—	—	—	—	—	—	—	—	—	(9[illegible],3[illegible]) a	22 a	—
14,	72	37	10·83	·02	·06	—	—	—	—	—	—	—	(118,[illegible]) a	2[illegible] a	—
15,	—	—	—	—	—	—	—	—	—	—	—	—	(118,[illegible]) a	[illegible] a	—
16,	—	—	—	—	—	87,360	4	8	—	—	—	—	—	—	—
17,	—	—	—	—	—	—	—	—	—	—	—	—	(141,120	45	—
18,	·85	37	12·29	·02	·06	—	—	—	—	—	—	—	143,360	45	—
19,	—	—	—	—	—	—	—	—	—	—	—	—	145,600	60	—
20,	1·10	36	12·60	·02	·06	87,360	2	—	82,880	11	112,[illegible]	28	120,960	27	—
21,	—	—	12·70	·02	·06	105,280	6	—	—	—	—	—	—	—	—
22,	·92	42	12·81	·02	·06	87,360	5	—	107,5[illegible]	20	129,[illegible]20	32	136,64[illegible]	37	—
23,	—	—	—	—	—	—	—	—	—	—	—	—	(143,360	45	—
24,	·85	·23	13·75	·02	·06	—	—	—	—	—	—	—	143,360	45	—
25,	—	—	—	—	—	—	—	—	—	—	—	—	147,840	49	—
26,	—	—	—	—	—	—	—	—	—	—	—	—	(136,640	48	—
27,	·85	·23	13·75	·02	·06	—	—	—	—	—	—	—	143,360	50	—
28,	—	—	—	—	—	—	—	—	—	—	—	—	145,600	51	—
29,	·85	28	14·01	·02	·06	8[illegible],64[illegible]	2	—	1[illegible]7,520	14	123,[illegible]	27	150,[illegible]00	44 (b)	—
30,	1·15	·84	14·27	·02	·06	—	—	—	—	—	—	—	154,560	46	—
31,	1·15	·84	14·27	·02	·06	—	—	—	—	—	—	—	156,[illegible]	4[illegible]	—
32,	1·10	32	14·48	·02	·06	87,360	1	—	101,76[illegible]	5	—	—	141,120	37	—
33,	1·24	16	15·36	·02	·06	109,760	8	—	105,280	2	—	—	156,[illegible]	31	—
34,	1·54	16	18·40	·02	·06	114,24[illegible]	1	—	87,360	1	—	—	118,720	1	—
35,	1·83	·26	18·55	·02	·06	96,320	1	—	—	—	—	—	123,[illegible]	5	—
36,	1·60	26	19·10	·02	·06	116,48[illegible]	1	—	91,840	1	—	—	132,160	4	—
37,	1·30	32	19·98	·02	·06	—	—	—	—	—	51,520	0	—	—	—
38,	2·10	46	21·69	·02	·06	8[illegible],64[illegible]	9	—	76,160	12	73,[illegible]20	11	—	—	—

"Natural state" means that the metal was simply cooled slowly after forging ceased.

"Air-toughened" means that, after cooling, it was reheated to a yellow heat and allowed to cool slowly in the air.

"Oil-toughened" and "water-toughened" mean that, after forging, it cooled slowly, was then heated to a yellow heat, and quenched in cold oil or water.

The fractures of bars with from three to nine per cent of manganese were always coarse and granular; those of bars with more than nine per cent of manganese which had been water-toughened were silky and fibrous.

The contraction of area of the water-toughened pieces is usually from thirty to forty per cent.

(*a*) Lowest, highest and average results of twelve tests.

(*b*) This piece is still unbroken. Hadfield, *Journ. Iron and Steel Inst.*, 1888, II., *excerpt Proc. Inst. Civ. Eng.*, XCIII, 1888, p. 40, *et seq.*

In the cast state, manganese steel is extremely brittle and hard. When forged, a remarkable increase in strength takes place, the tensile strength averaging about twenty-five tons, with three per cent. elongation.

Howe states,* "under stress, manganese steel acts very differently from wrought iron and carbon steel. With 125,000 pounds (fifty-six tons) tensile strength it may begin taking serious permanent set under stress of 35,000 pounds per square inch, so in this respect it is little better than common soft steel with (say) 60,000 pounds tensile strength.

[*To be continued.*]

CONFLAGRATIONS IN CITIES.

By C. J. H. Woodbury,

Vice-President Boston Manufacturers' Mutual Fire Insurance Company, Boston, Mass.

[*A lecture delivered before the Franklin Institute, Philadelphia, Jan. 23, 1891.*]

The lecturer was introduced by the Secretary of the Institute, and spoke as follows:

Members of the Institute, Ladies and Gentlemen:

Cities have always been an expression of civilization, measured by the skill and enterprise of their builders. Every human resource, stimulated by sentiment for home, avarice for possessions, and desire to be equal to posterity, has contributed means for fashioning them with a view to the utmost permanence; yet their history has been a continuous record of conflagrations whose devastating lines form historical divisions, separating the old from the new, and making swaths which have often proved to be paths for new improvements, but achieved at oppressive costs which would never have been entered upon voluntarily by the owners of the property destroyed. Most of these fires have resulted in forcing reforms in regard to streets, buildings,

* *Metallurgy of Steel*, p. 363.

laws and health. Blessings they may have been, but to those directly interested at the time, most completely disguised.

The accounts of early fires ascribe them to the visitation of an angry Jehovah or Jupiter, by the exercise of a supernatural power, and it is indeed without question that many of these instances of destruction were the result of natural causes, as earthquakes, volcanic eruptions and lightning.

However, little is to be feared from the latter form of visitation by any possibly reprobate city of to-day; thanks to the inductive effect, as well as the direct diffusion of the lightning by the much-abused overhead wires, which serve as a guardian between the earth and the sky, robbing the thunderbolt of most of its former dangers.

The Christian Era is only midway back to the earliest account of the burning of a city, contained in the Holy Writ [Gen. xix.], describing the rain of fire and brimstone on Sodom and Gomorrah. So terrible was this devastation that the once fertile sites of these cities are to this day a sterile waste.

It is evident from the record of laws fixing penalties for such crimes, that human agency was well recognized as a criminal cause of fires among the ancients. Among the Egyptians arson was punishable with death, and the Mosaic law, enacting a similar penalty, was probably a repetition of the same. In China it is forty blows for an accidental fire, and 100 blows for a malicious fire in one's own house, and for causing a fire in any other house, death.

Notwithstanding these severe penalties and the absence of insurance policies, the cities of the Orient, largely built of bamboo covered with thatch, and having narrow lanes, though well fitted to withstand earthquakes, are continually subject to conflagrations. One who was a resident in China for many years has stated, as a matter of opinion, that he considered the average existence of dwellings in cities to be about five years.

In Japan, so-called fire engines, consisting of square, wooden pumps attached to tubs, are hung from verandah roofs. [Morse, *Japanese Homes*, p. 65.] These devices are of

insufficient capacity and generally out of repair, like much of the independent fire apparatus among Occidental nations, and the main reliance is upon mud or stone buildings in the yard at the rear of the houses. These serve as safes in which the household goods can be stored in face of threatened conflagration. Such buildings are called by the Japanese, "kura," and by foreigners, "go-downs," although the latter term is also applied to store-houses owned by Europeans.

Oriental cities have been devastated by fire again and again. The courses of such conflagrations have been plotted on maps of Japanese cities by Dr. T. C. Mendenhall, Superintendent of the United States Coast Survey, formerly of the University of Tokio, and later of the United States Weather Bureau, and it has been found that the general trend of these fires is coincident with the direction of the prevalent winds.

Historical Fires.—Among the great fires of history, undoubtedly the burning of the Serapæum Library, at Alexandria, in the year 640, by the Caliph Omar I, is most widely mourned, as the destruction of 500,000 volumes cut off much of the record of human knowledge at that time. The general impression of the importance and significance of this fire is, no doubt, augmented in great measure by the barbaric answer of this Saracen conqueror, who replied to the protest against the burning with: "If the books are against the Koran, they are pernicious and must be destroyed. If they agree with the Koran, they are redundant and need not be preserved;" and it is not generally remembered that Julius Cæsar burned a larger library of 700,000 volumes at Alexandria, known as the Brucian Library, B.C. 48, nearly 700 years before the burning of the Serapæum Library by Omar I.

At times of sack and pillage, Jerusalem has been burned time and again; the most noted instance being at the siege by the Romans under Titus, during the year 70, when a faction called the Sicarii set the city on fire in many places, and eventually 1,100,000 of the inhabitants perished by fire and the sword.

Constantinople has, like all Oriental cities, suffered severely from fires, a large part of such losses being undoubtedly due to the fatalism of the Mohammedans, who bow to their kismet. Said a Sultan: "If it be the will of Allah that my favorite city burn, it is the will of Allah."

In Dillaway's quaint account of travels in the Levant in 1737, it is stated that the Sultan is summoned three times to a fire in Constantinople, and if the fire lasts an hour he is obliged to attend in person, and bring mules laden with piastres for the firemen. The proverbial liberty during fires exists on these occasions, for custom gives to the women the privilege of execrating the Sultan with impunity whenever he appears at a fire.

But it is evident that this custom of receiving piastres and bestowing virulence has in nowise tended to diminish the fires any more than the system of giving a reward to the company first at a fire under the volunteer departments of the last generation effected such results.

Rome continues to be the eternal city in spite of numerous fires, whose reported number may be greater than that of any other historical city, merely because the records are more perfect. Many of these fires are of great interest at the present day, because the lessons which they taught were well learned, and gave rise to new and original methods in preventing the repetition of the same incidents.

A great fire at Rome 12 B.C., caused the Emperor Augustus to take measures for increasing the defence against fire, which had been hitherto in the hands of bodies of police, numbering twenty or thirty, stationed in various portions of the city, and reinforced at times of fire by companies of volunteers. He appointed new officers with the rank of magistrates, who were entitled to wear magisterial robes. Each was attended by two lictors, and provided with a fire organization of 600 slaves.

It is probable that this was not entirely satisfactory in its operation, because six years later another fire caused him to undertake further reforms on a scale fully characteristic of him who "found the city built of brick, and left it with palaces of marble." He increased the fire department

to a scale commensurate with the needs of the city. Seven thousand freemen were organized into seven battalions, and one battalion was quartered in every alternate ward of the city. These men made careful inspections of the kitchens, of the heating apparatus, and of the water supply in the houses; and every fire was the subject of judicial examination. The cost of the organization was maintained by a tax of twenty-five per cent. on the sale of slaves. [See *Ancient Rome*, Lanciani, pp. 221-230.]

It is undoubtedly true that this organization, to which only a brief reference has been given, was of the greatest efficiency, for I can find no reference to any great fire in the city for seventy years, when it was set on fire by the Emperor Nero in the year 64. The account of this fire, given by Lanciani, as the result of the latest investigations, is so different from the generally accepted tale of the city being set on fire by the malice of Nero, "who played the fiddle while Rome burned," that the recent version may be of interest.

Nero desired to make many changes in the streets of Rome by increasing their width and making many of them more direct, and also to introduce many improvements by reconstructing public buildings. His efforts in this direc- were met by an opposition from property-owners, and were also embarrassed by the fact that the city abounded in temples, altars and shrines which were inviolate.

The Emperor directed two architects, Severus and Celer, to prepare plans for a re-arrangement of the streets in certain parts of the city, making them as near to straight lines and right angles as the hilly configuration would render feasible. Numerous public squares were laid out and a system of sewers planned.

Regulations for buildings were prepared, in which it was provided that the height of houses should not exceed double the width of the street, that each house should be completely cut off from the adjoining buildings, that each house should have a portico in front, and that wood ceilings should be excluded from the first stories of buildings.

Tents and booths were secretly prepared, and vessels were

sent to various Mediterranean ports after grain with orders to rendezvous at the delta of the Tiber on a certain date. In accordance with his plan the city was fired in numerous places, and of the fourteen wards, three were entirely destroyed and seven burned in great part.

The crowds driven out of their homes found the booths in the outskirts of the city ready for them. The grain-laden vessels appeared in time, and the towns-people were fed and housed during the rebuilding; the whole plan having been carried into effect without exposure, famine, or loss of life, although the population numbered at the time 2,000,000.

Improved hygienic conditions have been the usual result of conflagrations, because in the natural course of events those engaged in rebuilding have availed themselves of opportunities to introduce improvements, and often the causes leading to certain local epidemics have been destroyed; but it is without parallel that a city should be burned from hygienic motives.

Two notable examples of contagions stopped by conflagrations are the burning of Moscow by the besieging Tartars, in July, 1570, when the plague was stopped, and secondly the fire in London, September 2, 1666, which also stopped the plague, and it has been unknown there since.

This London fire is properly called the Great Fire of modern history, because the reforms which were started in consequence of it are living issues in the municipal affairs of to-day. The fire was caused by an overheated baker's oven; and in the course of four days it swept over 463 acres, burning 13,200 houses, eighty-nine churches, and St. Paul's Cathedral, causing a damage estimated to be £10,716,000, say $53,500,000.

The number of contemporaneous books upon the subject of this fire is between 200 and 300, but the greater part of them, judging from the list of their titles, contains but little information. The wonderful diaries of Samuel Pepys and Sir John Evelyn contain about all that is known in regard to this fire. Pepys was a man of the world, among the official set as Secretary of the Admiralty, a keen

observer, and perhaps a journalist born out of due time. Evelyn was one of the gentry, complacent, more than pious, and quite philosophical in the bent of his mind. The one was the most perfect foil for the other.

Under the direction of Pepys the fire was stopped by blowing up buildings, which was, at the time, the only method of reducing a fire that had grown beyond the capacity of the small fire engines. These were on large tubs, and threw a stream of water directly on to the fire, as hose was not invented until ten years later (1672) by Van der Heide.

Important results followed the action taken in consequence of the great fire. The building regulations enacted provided for the reconstruction of the city with wider streets and better water supply and sewers—thus fitting London for the position of great commercial supremacy which that city has since maintained. The principle of modern fire insurance was also put into practice shortly after the fire and as a consequence of it.

At a far earlier date there had been a form of marine insurance, and also a method of mutually indemnifying against fire, water and robbers, by the guilds, but both of these were by a mutual compact, socialistic in its nature, and not comparable to underwriting in modern practice, with its general commercial applications.

All cities have gained much from the experience derived from conflagrations. The French building laws are said to have been improved in great measure from action taken as a result of a fire in Paris, in 1716, although the *Code Napoleon* (1804) increased these rules and restrictions to an extent praiseworthy in its results, of which the best statement in English is probably in the paper by W. L. Boswell, "Fire Defences of Paris." [*Journal Franklin Institute*, February, 1890.]

The firing of cities has been used as a desperate means of defence, which injured friends and foes alike; one notable instance being the burning of Jerusalem by the Sicarii, to which reference has already been made.

Another example of burning a city in self-defence is the

burning of Moscow, September, 1812. Napoleon, in his campaign against Russia, in revenge for his repulse as a suitor for the successor of the yet undivorced Josephine, entered Moscow, September 14th, proposing to make winter quarters there. On that very day fires began to appear, and in less than a week the city was in ashes. The loss of life is said to have been 20,000 of the sick and wounded, with a direct loss to the French of 40,000. The invaders were thus driven back in that terrible retreat in the dead of winter.

The cities of America, on account of the larger amount of wood in their construction and the prevalence of irresponsible methods of building, have suffered severely from fires, and it is from these fires that conclusions are to be drawn for suggesting measures that will tend to diminish their recurrence.

Some of the possible elements of hazard, like those due to electricity or to very high buildings, are too new for their exact weight to be formulated; and others, like the attempt of the Indians to burn New York in 1711, have ceased to exist, at least in the older portions of the country. But such hazards have always existed at the frontier in the westward growth of civilization, and the daily papers contained an account of the burning of the town of Pocatello, Idaho, by the Indians on the eighth of this month. I do not, however, care to discuss the insurance liability from this hazard.

The first devastating fire in America was probably the one occuring at Boston, March 20, 1760, when 400 dwellings and stores were burned, causing a loss of £100,000. Generous contributions were sent from other cities to the people of Boston; and in 1811, when a large portion of the city of Newburyport was burned, the citizens of Boston, with a liberality which they have never failed to tender to other cities that have suffered by fire, took the initiative in subscribing for the relief of the sufferers.

In the Colony of Massachusetts Bay, regulations in regard to construction of chimneys and thatched roofs were made as early as March 16, 1630, and various enactments were made at later dates. The ordinance at the town-meeting at Boston, March 14, 1645, made provision that each house-

holder should have ladders long enough to reach the ridge of his house, and a pole "about twelve feet long, with a good large swab at the end of it;" and various graded penalties were provided for those not conforming to the law. [*History Boston Fire Department*, Brayley, p. 7.]

It is difficult to obtain a record of early American conflagrations outside of local histories. New Orleans was burned in 1777, and every city seems to have had more or less of similar calamities.

Philadelphia has been remarkably free from conflagrations in comparison with other large cities. This may be in part ascribed to the early introduction of water, giving that city for several years an advantage in the way of an abundant supply of water. In a greater measure it is due to the abundance of land, making it feasible to avoid the density of buildings which is common to most cities; and in chief measure it is probably due to the prevalent and wise custom of people owning their homes, a fashion which in many other respects tends to prosperity and good order.

Reference has been made to numerous fires on account of their relation to the growth of various methods of protection; but in Philadelphia it appears that the excellent record is due to the initiative measures, beginning with the act of the Provincial Legislature, in 1696, directing that every householder should keep at his dwelling a bucket ready for use, and a swab twelve or fourteen feet long, under penalty of twelve shillings for neglect, and forbidding the burning out of foul chimneys, penalty forty shillings, and the smoking of tobacco on the streets day or night, the fine for the latter being ten pence.

The first insurance written with American capital was probably marine insurance, written at Philadelphia, in 1721; although marine insurance on vessels owned at Philadelphia was written in London shortly after 1683. [See *History of Insurance in Philadelphia*, by J. A. Fowler.]

New York was visited by a severe conflagration in the southern part of the city, on December 16, 1835, which extended over an area of forty acres, destroying 674 houses and causing a loss which has been estimated as high as

$30,000,000, on which there was only $8,000,000 insurance, an amount which ruined several insurance companies. It has been held by some that the destruction of property by great fires has rendered them the cause of financial depressions; and in this connection it has been stated that this New York fire was the cause of the panic of 1836.

Philadelphia does not appear to have been visited by a great fire until July 9, 1850, when a fire along the Delaware River front, at Vine Street, extended over eighteen acres, causing a loss of life estimated as high as thirty-three, in addition to 120 wounded, and a pecuniary loss of $1,500,000.

The memory of this fire is perpetuated in the slang of to-day. An explosion was caused by a coincidence in the contents of a warehouse which contained sugar in the upper stories and saltpetre below. When the saltpetre came in contact with the sugar a violent explosion ensued, and for a while spread the fire beyond all efforts to control it. This catastrophe and the controversies which followed it gave rise to the satirical question: "Will saltpetre explode?" and was followed by an ordinance forbidding its storage in quantity in the city or on vessels in the river. This act was afterwards modified (April 14, 1851).

A greater fire occurred August 4, 1869, when, by the burning of Patterson's bonded warehouse, at Lombard and Front Streets, 24,000 barrels of whiskey were burned, gutted or stolen, causing a loss of about $2,000,000. If other large fires have conduced to order and wiser laws, the direct result of this fire led to disorder, for the opportunity of drinking without stint or price proved too great a temptation for many, and the temperance cause languished to an extent without precedent.

One of the first of the more recent conflagrations was the burning of Portland, Me., July 4, 1866. The fire was caused by a boy throwing a fire-cracker into a cooper's shop, for the avowed purpose of scaring the workmen. In this respect the act was an unparalleled success, the damage being about $10,000,000.

The eloquent letter of John Adams, July 3, 1776, after the resolution preceding the Declaration of Independence

had been passed, in which he said of the Fourth of July: "It ought to be solemnized with pomps, shows, games, sports, guns, bells, bonfires and illuminations from one end of the continent to the other, from this time forward forever" [*Letters of John Adams to his Wife*, p. 128], has many catastrophies to answer for.

The Chicago fire, October 9, 1871, was one of the largest in all history, devastating an area of three and one-half square miles, and causing a loss of about $190,000,000, on which insurance was paid to the amount of about $100,000,000. Two hundred and fifty lives were reported lost in this fire.

Thirteen months later, to a day, Boston was visited by a fire which extended over an area of sixty-five acres, burning the best mercantile buildings in the city, and causing a damage of $75,000,000, on which there was insurance to over $65,000,000.

Inspection.—As in other instances, these casualties gave rise to many plans for better building laws, and for the reorganization of fire departments. In the course of such changes many acts of injustice have been perpetrated by those who did not grasp the whole force of the chain of circumstances causing these devastating fires, conditions too strong to be controlled by any one set of rules formulated at white heat after a conflagration.

These cities had great fires, and will, in the nature of things, have other great fires. Conditions exist which, in the event of fires starting in certain localities and of any error in promptly giving the fire alarm, cannot fail to produce disastrous results.

The causes of fire are as infinite as the varying conditions of the numberless possessions of mankind; and beyond that the forces of nature contribute in no small degree to the fire loss.

Whether it be the overheated baker's oven at London, the balky cow at Chicago, the neglected waste in the engine room at Boston, all great fires result from neglected small ones.

Every method of construction, every process of manu-

facture, every material in commerce, as well as every type of fire apparatus, and the orderly conduct of affairs bears some relation to the fire hazard. The function of the underwriter is not merely to give to these elements their just weight, but yet more to rise from a consideration of physical conditions to the higher and ethical questions relating to the moral hazard as measured by the probity of owners, who are always possessed of every opportunity to effect the destruction of their property by fire. The facility with which insurance can be effected, and the readiness with which losses are paid, renders incendiarism the great undetected crime of the present day.

It requires no argument to prove that the most efficient means of diminishing the amount of loss by fire is to lessen the number of causes of fire; but the best method of carrying such measures into effect is a question upon which there are legitimate differences.

Inspections by men employed by associations of underwriters have given the most satisfactory results, but it may justly be queried whether this is the proper source for such an espionage over the community. These inspectors are employed by associations composed of competitors in the insurance business, and they are without any legal authority to enforce obedience to suggestions which are admittedly for the weal of all.

Their requests are, for the most part, complied with; but the results are a benefit to the community, and it would appear that this service should be performed by persons clothed with authority from a municipality, as a part of the protective system which now extends protection to person and property by means of the police, the water supply, and the fire departments, leaving to the underwriters their legitimate work of insuring property at prices based upon the estimated hazard. If the risk of destruction by fire is reduced, it will be a benefit to the community, which will be gladly recognized by underwriters in the diminution of premiums based on the new condition of affairs.

The methods of fire patrol carried on by members of the fire departments in many cities do not comply with the

offered suggestions. There should be a patrol by members of the fire department, who should systematically inspect every building, searching into every preventable cause of fire, with authority to cause the proper remedies to be carried into effect. The building laws refer almost solely to the new buildings erected within a few years, but a commission like this would be able to introduce inexpensive modifications into old buildings, which would greatly modify many dangerous conditions of hazard.

[*To be continued.*]

PROF. LIPPMANN'S HELIOCHROMY.

By F. E. Ives.

[*A communication to the Chemical Section, April 21, 1891.*]

At the March meeting of this section, I made some comments upon the alleged solution of the problem of photography in natural colors by Prof. Lippmann, of Paris, expressing some doubt as to the possibility of obtaining such alternate zones of "light and darkness" in proximity to the mercury mirror as are called for by Prof. Lippmann's theory, and also as to the possibility of reproducing the compound colors by means of interference laminæ. I afterwards communicated my doubt to Prof. Himes, of Dickinson College, and asked for an expression of his opinion. He kindly wrote me a long letter, from which I quote as follows:

"As far as I have been able to follow Prof. Lippmann, I am more hopeful than you perhaps are in the direction of compound colors, and more nearly satisfied with the theoretical explanation, although, of course, at this early stage it must be regarded, of course, only as provisional, and there are many questions that both of us would like to ask, some of which Prof. Lippmann might possibly be able to answer by this time and others I am just as certain he could not. I will just note hastily the points upon which I have less difficulty and doubt than you seem to have, premising first

that you concede the fact that Prof. Lippmann has succeeded in getting a photographic impression of the spectrum in which can be recognized at least the colors in their order—some say brilliant and perfect—but I think Prof. Lippmann's account is more moderate and modest. But this is not the greatest feature of Prof. Lippmann's publication. This has been done long ago and by many, and possibly better than he has accomplished it, but he has succeeded in *fixing* it, and that by the ordinary photographic method, and his whole process, withal, is so simple and complete that it invites and encourages experiment with it, which I have great hope will lead to practical results.

"As to his theory we may think what we please. With me it has this in its favor, that the appearance of all previously obtained heliochromic results by Becquerell and others, whether flowing from systematic investigation or from accident, as in many cases, conforms to that of Prof. Lippmann's results, and can best be described as that of *interference* colors. There are even those who intimate that after all Prof. Lippmann adopted a theory and line of investigation already outlined.

"I have no difficulty in regard to the interference of direct and reflected waves so as to produce so-called stationary waves of definite length and frequency. The ocular demonstration of such waves, usually employed in lectures, by means of a stretched spiral cord or gum tube, attached at one end to a hook, and held at the other end by the hand, on which regularly timed impulses by the hand produce interfering direct and reflected waves, is very satisfactory at this point. The completed analogue in case of sound is to me conclusive of the plausibility of the theory of Prof. Lippmann. Savort, in the early part of the century and more recently Lord Rayleigh (in 1888) by a series of classical experiments demonstrated the presence of stationary sound waves, with their spaces of sound and silence by the interference of direct waves with those reflected from a board using a sensitive flame to explore the space. A double reflecting surface may be necessary to present interference colors to the eye as you state, as the rays should both be

moving toward the eye, but to produce the stationary luminous undulations, or zones of maximum movement or maximum energy and zones of rest or of minimum movement; of the ether particles, the interference of an incident and reflected ray from one surface will be sufficient condition. These are hardly to be called zones of light and darkness. A ray of light is invisible as such; it produces visible effects, so here the zones of differing energy in the ether particles produce varying effects upon the film in which they are formed, effects which we recognize as photographic.

"These effects are not the production of pigment colors, as up to this time seems to have been the expectation in heliochromy, but they are rather in nature of change of structure, laminated deposits of silver, so to say.

"As to the rendering of compound colors, I have not seen much claimed as accomplished in this direction. There is a well-grounded hope, I believe, but the rendering of the spectrum and the perfect fixing of it are the chief claims of Prof. Lippmann, as I understand it. I would not draw, or allow the theory to draw, the line of the impossible too near to the present achievement to prevent investigation and experiment with compound colors. The whole doctrine of perception of compound colors would not permit us to deny such possibility. Prof. Lippmann has certainly started scientific thought and investigation, as far as heliochromy is concerned, in a new direction, by results that commend our admiration and a theory that is not only possible, but a most excellent working hypothesis."

Capt. Abney, who recently visited Prof. Lippmann, also appears to endorse his theories, but does not regard his process as a step in the direction of practical photography in colors. The following report of Capt. Abney's remarks upon this subject, at the recent Camera Club Conference, is from the London *Photographic News*, of April 10th:

"Photography in natural colors was the next question to which the President turned his hearers' attention. The 'accomplished fact,' as some of the newspapers led their readers to suppose, is as old as photography, for the discovery of photography in colors has been made, according

to some people, over and over again. Being in Paris a week ago he had the opportunity of visiting M. Lippmann. He found that gentleman to be a true man of science, with all the modesty of a real investigator. The color plates about which we have heard so much are due to interference, and not to pigments, and their effect varies according to the angle at which the plate on which they appear is held. Capt. Abney then proceeded to describe how these colors are obtained, by use of a mercury trough, as already detailed in our pages. He pointed out that, to obtain the colors, exposure to a bright spectrum was necessary, and that development must be brought about by alkaline carbonates, and the image intensified with silver. Both exposure and development must be exactly correct, or no colors are apparent, and the best results are gained with dry plates prepared with albumen and collodion. He looks upon the results of M. Lippmann's experiments merely as a verification of Newton's law, and not as a discovery of photography in color. M. Lippmann has certainly succeeded in fixing interference colors, but the process is clearly one of extreme difficulty. It is a misfortune both for M. Lippmann and his predecessor, Dr. Koch, that their experiments should have been dealt with by the ordinary reporters, because these reports have led the general public to expect far more than the experiments in either case justified."

COMPOSITION OF BOILER SCALE AND THE COMPOSITION OF THE FEED WATER FROM GALVESTON, TEX.

By George A Koenig.

[*Read at the stated meeting of the Chemical Section, held June 16, 1891.*]

The city of Galveston is built upon a narrow tongue of land which separates the Gulf of Mexico from Galveston Bay. I am informed that the surface of this land consists of a conglomerate or natural concrete, some twelve to eighteen inches thick. Over this extends sand three to four feet thick, and under the concrete a bed of quicksand of very great depth; its depth being practically unknown. The conglomerate offers very good foundation for all buildings. To obtain feed water for steam boilers, several of the industrial establishments have driven tube wells into the quicksand to great depth. The well of the Galveston Rope and Twine Company, whose water is the subject of this paper, is said to be 1,500 feet deep. It is probable that the sinking was continued until the flow of the quicksand stopped.

The water from this well is perfectly clear, and no sediment was found in the vessel. It has a very salty taste, and contains, in 1,000,000 parts:

SiO_2,	=	29·9
Fe_2O_3,	=	3·5
Al_2O_3,	=	1·5
CaO,	=	132·8
$MgCl_2$,	=	197·6 (MgO = 83·2)
$NaCl$,	=	5489·3
SO_3,	=	1·99

CO_2 was not determined; but from the composition of the scale it must be inferred that there is probably a little more CO_2 present in the water than is required to hold the calcium in solution as hydro-carbonate. Since the percentage of sodium chloride is 0·55, and since the sea washes, so to speak, the very locality, the conclusion might easily be reached that this artesian water is simply filtered

sea water. This view is surely entertained at the locality, and is also held by some chemists. There are several reasons why this view must be abandoned. The supply of these artesian wells has nothing in common with sea water. An analysis of the water taken in the surf of Atlantic City this spring gave me, in 1,000,000 parts:

$(SiO_2 + Al_2O_3 + Fe_2O_3)$,	=	6·0
SO_3,	=	1965·0
NaCl,	=	23320·0

Sea water, then, contains about one-fifth as much of silica, ferric and aluminum oxides; it contains 1,000 times more of SO_3 and over four times as much of NaCl. What could have become of the sulphates if this artesian water were filtered sea water? It is simply inconceivable to suppose that the filtering through fine quartz sand would remove the sulphates, which are very soluble. We might understand that the flowing through the quartz would increase the silica in the water, but again we could not account for the loss of three-fourths of sodium chloride. Thus we are brought to the only possible explanation, namely, the existence of a deposit of rock salt under the quicksand. We know that there is such a deposit at the mouth of the Mississippi River, of probable Miocene age, and which has been exploited for many years. We know that whenever a salt bed forms from evaporation out of sea water the sulphates crystallize out first; the salt always overlies either anhydrite or gypsum, even the kieserite ($MgSO_4 + H_2O$) is found at Stassfurt, in the lower levels. The top beds always contain the easily soluble chlorides of magnesium and calcium and potassium, as at Stassfurt, but not necessarily everywhere. I tested five grams of the salt obtained by evaporation of the Galveston water for potassium, but found much less than there is in the sea water at Atlantic City. This is surely another anomaly, but notwithstanding, I think the evidence is strongly in favor of assuming the top strata of a salt bed as the source of the Galveston artesian water. The Galveston Rope and Twine Company having observed that the boiler-plates of a neighboring establishment had been very rapidly destroyed by the forming of

pin holes, resolved to have the matter investigated before their new boilers (from the Edgemoor Iron Company) had suffered a similar fate, and sent samples of their feed water as well as of their scale. After investigation, the writer proposed the use of soda ash as a preventive. But some other parties having recommended tri-sodium phosphate, a new sample of the scale was submitted some four weeks later. The analyses of both samples (*A*) before and (*B*) after the use of the tri-sodium phosphate are here given:

	A.	*B.*
SiO_2,	= 11·86	18·76
Fe_2O_3,	= 2·80	2·40
Al_2O_3,	= 0·30	0·66
P_2O_5,	= 0·10	0·58
CaO,	= 9·20	7·64
MgO,	= 43·74	40·28
CO_2,	= 8·86	9·72
H_2O,	= 23·14	19·96

The scale is thin and gray in color. It disintegrates easily. Under a power of 500 diameters it is resolved into an aggregate of single crystals, some prismatic, some tabular. The latter show a hexagonal combination of the basal plane with a positive and negative rhombohedron and resemble the mineral brucite (MgH_2O_2). The prismatic crystals are six-sided with the basal plane. However, they appear to be orthorhombic from their behavior in polarized light.

The substance gelatinizes with hydrochloric acid. There must be consequently a silicate present. The variation in the percentage of silica (this has been called sand, erroneously) is striking. It would be very interesting if the nature of the silicate could be ascertained. It might by chrysolite, which gelatinizes with hydrochloric acids. Assuming this to be the case, and it seems probable because the form is orthorhombic, analysis *A* would assume the following min eralogical interpretation:

Chrysolite (Mg_2SiO_4),	= 27·67
Aragonite ($CaCO_3$),	= 16·4
Hydromagnesite ($CO_3Mg_2H_2O_2$),	5·0
Brucite, (MgH_2O_2),	37·0
Götheite $(FeH)O_2$,	3·2
Hygroscopic water, etc.,	11·0

It is clear that the destruction of the boiler iron is caused by the formation of magnesium hydrate from the chloride, according to the equation

$$MgCl_2 + 2H_2O = MgH_2O_2 + 2HCl$$

If a sufficient quantity of Na_2CO_3 be added to the water, there is no precipitate formed at ordinary temperature; but at 80° C. a flocculent deposit follows of magnesium or calcium carbonates.

Analysis *B* shows that the tri-sodium phosphate had very slight effect. It would not be well to reject it on this account, because it may not have been introduced properly. But it seems to me that the carbonate should be recommended in such cases. The latter is on trial at Galveston now, and after some time another sample of the scale will be submitted.

EWING'S THEORY OF INDUCED MAGNETISM.

By Prof. Henry Crew.

[*Read at the meeting of the Electrical Section, held May 5, 1891.*]

The labors of Rowland, Stoletow, Wiedemann and Ewing have brought to light so large a number of magnetic phenomena that any general principle on which they may be explained would receive a warm welcome at the hands of all interested in this rapidly growing subject.

Any generalization of this kind would be called upon to explain the following phenomena, which are selected each as typical of a large *class* of well-known facts.

(I) *The behavior of a piece of iron when placed in a magnetic field whose strength is made to pass through a cycle of changes.*

(*a*) For magnetizing forces ranging from $\frac{1}{50000}$ to $\frac{1}{25}$ of a C. G. S. unit, the intensity of magnetization is proportional to the magnetizing force (Rayleigh, *Phil. Mag.*, March, 1887).

(*b*) For a range of magnetic forces extending (roughly) from $\frac{1}{25}$ to 5 C. G. S. units the magnetization increases with a rapidity enormously greater than the strength of field.

(*c*) From this point on, as the force continues to increase

the permeability decreases and the induction approaches a limit which, the work of Ewing and Low (*Phil. Trans.*, 1889), leads us to think, has for a value about 40,000.

(*d*) If now the magnetizing force be diminished, the magnetization diminishes, *but not so rapidly*, until, when all the force is withdrawn, there still remains a perfectly definite magnetization, which is used as a measure of the "retentiveness" of the iron under the conditions of the experiment.

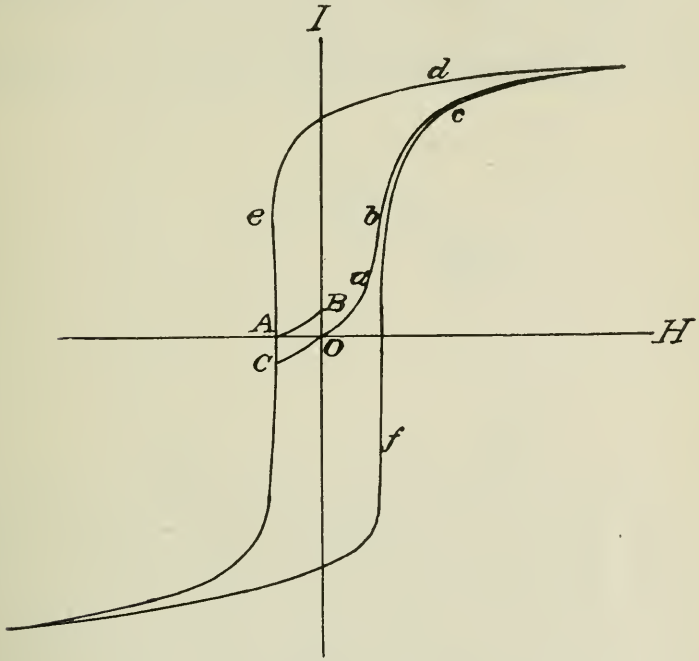

FIG. 1.

(*e*) If next the magnetizing force be reversed the magnetization will rapidly diminish, and at a certain negative value of the magnetizing force, the magnetization of the iron will presently reach a zero value; but, if the current be broken the magnetization will "spring back" along the line *A B* (*Fig. 1*).

In order to destroy the magnetization of the iron we must pursue our way along the curve to a point at *C*, such that when the current is withdrawn and the magnetization

falls, it will fall along the line *C O*, from *C* to *O*. The iron here, however, will have magnetic properties quite different from those which it had before magnetization.

(*f*) Having reached a large negative value we obtain, on gradually diminishing the force and allowing it to increase in the opposite direction, a curve corresponding to (*e*) and (*d*), and nearly symmetrical on the other side of the axes of *I* and *H*.

The curve *a*, *b*, *c*, *d*, *e*, *f* is a graphical summary of the now well-known facts of hysteresis.

(II) *Nearly all reversals of sign in the change of the magnetizing force are accompanied by small changes in the magnetiza-*

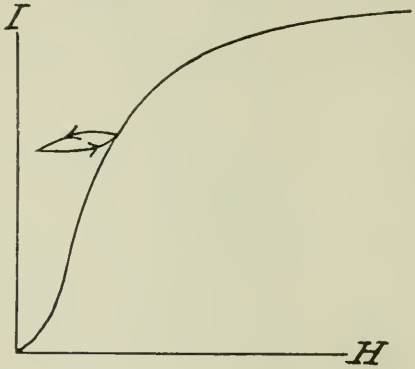

FIG. 2.—Illustrating the effect of a small superimposed cycle in the magnetizing force.

tion. In the magnetization curve any reversal starts out along a nearly horizontal line. (*See Fig. 2.*)

(III) *The fact that a piece of iron submitted to vibrations or mechanical shocks is magnetized and demagnetized more readily and with a smaller hysteresial area than if it remains undisturbed.* The *I H* curve then takes a form of which *Fig. 3* is a type.

(IV) *The phenomena of "time lag" in magnetization.* Ewing finds his magnetometer needle creeping up long after the time when Foucault currents or self-induction could have any effect.

Rayleigh (*Phil. Mag.*, March, 1887) finds that with a second coil he can balance the effect of a magnetizing coil and iron core, at the end of any given time, say five seconds.

If balance is obtained at the moment of making the magnetizing current, then at the end of five seconds there will be a deflection of the magnetometer in *one* direction. But if the balancing coil is so arranged as to give balance at the end of 5 seconds, then there will be an *initial* deflection in the *other* direction.

(V) *Phenomena of stress and magnetism.* These are usually grouped under two heads, viz:

(*a*) Those which occur when a body has first been placed in magnetic field and the stress then made to vary.

(*b*) Those which occur when a body is first placed under a constant stress and the magnetizing force is made to vary.

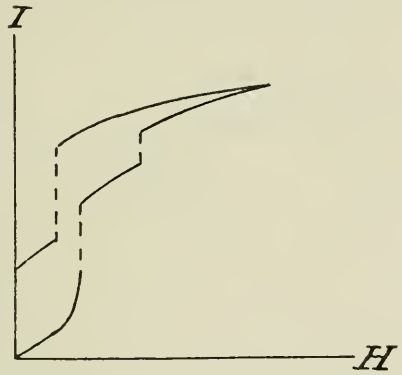

FIG. 3.—Illustrating the effect of tapping on the *I H* curve.

The hysteresis between magnetization and stress may be best illustrated by the curve in *Fig. 4*, derived by Ewing (*Phil. Trans.*, 1885) from experiments on a piece of iron which had been previously strained.

If, however, the wire be a freshly annealed and unstretched one, then the hysteresis is much larger, and we obtain a curve like that in *Fig. 5*, the maximum on the down curve corresponding to a negative load, *i. e.*, to a pressure.

The effect of a *constant* load on the *I H* curve may be seen in *Fig. 6*.

From this it will be seen that longitudinal stress aids magnetization at first, but for larger values of *H* it diminishes it.

(VI) *Effects of heat on magnetization.* In general, perma-

nent magnetism is decreased by heating through any cycle of temperatures. But in the case of induced magnetism we must distinguish between two cases:

(*a*) When the heating is not high the effect is to increase the susceptibility.

(*b*) When the heating is excessive, it decreases the susceptibility.

The foregoing are a few of the hundreds of facts which experiment has recently brought to light. Any tolerably complete explanation of them must include two parts, viz:

(*a*) An explanation of the ampèrian currents (or of molecular magnets on some other hypothesis.)

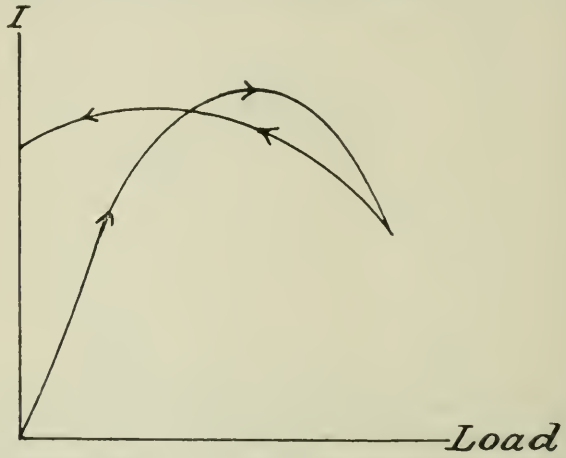

FIG. 4.—Effect of loading an already strained iron wire in a magnetic field.

(*b*) The *arrangement* of Weber's molecular magnets in the mass.

We are here concerned only with the second and apparently less difficult part of the problem.

The first attempt at a theory of magnetic induction is that of Weber, who supposes the molecules of freshly annealed iron to be turned at random in all directions, and to be held in their respective positions by constant forces acting along their respective axes. This hypothesis explains the existence of an upper limit to magnetization; it also explains the experiment of Beetz, in which he obtains a strong magnet by the electrolytic deposition of iron in a

magnetic field; but is condemned by its failure to explain the phenomenon of permanent magnetism.

Maxwell, therefore, modifies Weber's theory by supposing that when the axis of a magnetic molecule is displaced through an angle greater than a certain limiting angle it receives a certain set. Thus amended, the hypothesis of Weber covers a much larger number of facts, *e. g.*, permanent magnetism, and the production of permanent magnetism by moderately high forces only. Maxwell's theory fails, however, to explain such a phenomenon as that of "time lag," which has been so elegantly worked out by Rayleigh and Ewing (*Roy. Soc. Proc.*, June, 1889).

In the *Philosophical Magazine* for September, 1890, Prof. Ewing offers the apparently bold hypothesis of no constraint

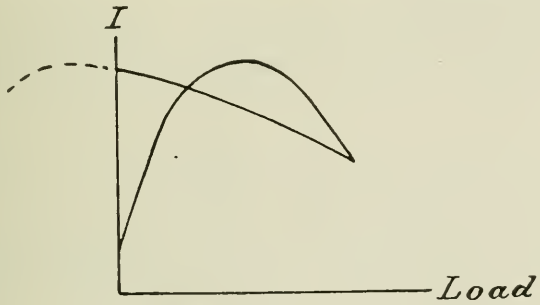

FIG. 5.—Effect of loading a freshly annealed iron wire in a magnetic field.

at all acting on the molecular magnets, save only their magnetic action on one another.

A large model, constructed on the lines suggested in the paper just mentioned, was here exhibited to the Section.

A helix, about three feet long and one foot in diameter, contained within it three tiers of magnets mounted on three glass decks. Each magnet was balanced on a needle-point, the whole arrangement showing in a striking manner the interaction of the magnets and the multitude of different positions of equilibrium which they may assume.

The sufficiency of this hypothesis may best be tested by applying it to explanations of the six typical facts just mentioned.

(I) Stirring the magnets up, with no current in the helix,

we observe that they arrange themselves very much at random, yet more of them pointing north than in any other direction. (The north poles were fitted with damping vanes.) This, of course, represents the magnetization of iron by the earth's field.

Balancing the earth's field by a slight current through the helix, and again stirring up the magnets, we have a piece of freshly annealed iron, with practically no external moment to start with.

A slight increment of current deviates the magnets to some extent, thus giving an external moment, but no new position of equilibrium is assumed, so that on bringing the current back to its initial value, we find the iron without any residual magnetism, which corresponds exactly to the fact of nature.

Increasing the current a little more, one observes a stray magnet now and then passing into a new position of equilibrium which corresponds to the part *a* of the curve in *Fig. 1.*

A little more current and these changes occur in a more wholesale manner, giving the part *b* of *Fig. 1.*

Increasing the strength of field to about two C. G. S. units, we find that all of the magnets have set themselves nearly in the direction of the field, an arrangement which corresponds to the asymptotic part of the *I H* curve.

Diminishing the magnetizing force by gradual steps to zero there remains considerable external moments, which, however, is destroyed and generally reversed by a comparatively small negative force.

In fact, the cyclic curve thus obtained bears a striking resemblance to those actually obtained from a piece of iron. In the *Electrical World*, May 16, 1891, Mr. Arthur Hoopes has three curves, taken from this model under different conditions.

(II) If for any given value of magnetizing field we reverse the sign of change in the current, the magnets will be observed to change direction very slightly, falling back into their nearest position of equilibrium, where they are held by each other until subjected to a change of more con-

siderable size. This, of course, is the second phenomenon mentioned above.

(III) One has only to shake the model, even slightly, to see the effect of tapping a piece of soft iron during magnetization or demagnetization. If the magnets be not very close together, it takes careful handling not to throw them into a new position of equilibrium.

(IV) Allow the magnets to come to perfect rest and then turn one of them with the hand through an angle of 40° or 50°. The disturbance will be propagated along the line at a comparatively slow rate. In this way, Ewing explains "time lag."

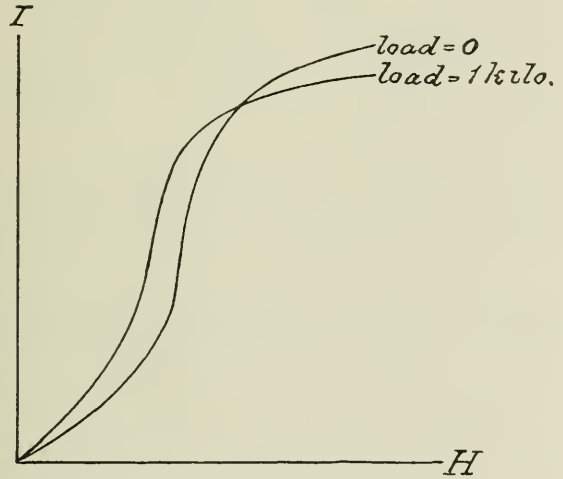

FIG. 6.—Illustrating the effect of a constant load on the *I H* curve.

The great while occupied by the magnets in coming to rest after they have once been disturbed by a change of current, continually increasing or continually decreasing, their external moment, chimes in beautifully with the work of Rayleigh mentioned in "IV" above.

(V) The effect of stress on magnetization is stated as follows in terms of the model by the author of the theory (*Phil. Mag.*, September, 1890): "When pulling stress is applied, those rows of molecular magnets which lie more or less along the direction of the stress have their stability

reduced by the lengthening of the lines of centres; similarly, rows which lie more or less normal to the stress have their stability increased. The resulting effect on the general susceptibility of the material will depend on which of these conflicting influences preponderates. Let pull be applied before magnetization begins, while the metal is still in a neutral state. The stretching of longitudinal lines and the contraction of transverse lines will not only alter the stability of those molecules which continue to lie in their original rows, but will tend to make the members of those rows which are much lengthened swing round and form transverse lines in which they will be more stable than before. We may, therefore, reasonably expect that the permeability with regard to strong fields will be reduced by pull, as it actually is both in iron and in nickel, though with regard to weak fields the permeability may be increased, as it is in iron.

"Again, the theory explains well why the effects of stress are by no means the same (1) when the stress is applied first and the magnetic force after, and (2) when the magnetic force is applied first and the stress after.

"Let a moderate magnetizing force be applied and then begin to apply stress. The first effects are in general large for the strain precipitates into instability those molecular magnets which were already on the verge of instability. This is beautifully apparent in iron (see *Phil. Trans.*, 1885, part ii, plates 63 and 64); and the theory shows why the first effects are not reversible, why they do not disappear when the stress is removed, and why it is only in subsequent applications and removals of the stress that the magnetic changes become cyclic."

(VI) The molecular motions accompanying heat will evidently free the magnetic molecules to some extent from each other and thus allow them more easily to place themselves along the axis of the magnetizing helix. The effect of heat will therefore be in the well-known direction of increasing the magnetization.

The effect of high heat in destroying magnetization is not, however, so readily understood. Ewing suggests that

it may produce rotation of the molecules and thus give the effect of zero external moment.

This much at least may be said, that nearly the whole group of magnets may be placed in rapid rotation by quickly reversing a strong current through the helix. Indeed, most any violent disturbance, such as a shock, will set a large number in rotation, which state they seem to maintain for a long while.

Some facts in the dynamical theory of heat lead one to think that this supposition of rotating molecules may not be so wild as at first it might appear.

The foregoing are some of the facts which fall into line, on the supposition of no constraint among the molecules except their own magnetic attraction and repulsion.

Prof. Ewing has given many more, and everyone should read his paper.

But there are a number of outstanding facts which do not submit so easily to explanation, *e. g.*, the difference of magnetic behavior with reference to temperature in the cases of nickel and cobalt. [*Ency.*, *Brit.*, art. "Magnetism," p. 257.]

It must not be forgotten that this model represents only one single phase of molecular arrangement. Chemical and spectroscopic phenomena indicate a vastly more complicated structure for the molecule than has yet been dreamed of. However, it is interesting to note that Prof. Ewing's hypothesis leads to conclusions which have already been derived from other lines of work.

For instance, the distinction between hard and soft iron in terms of the model is that in the former case the molecules are grouped more intimately than in the latter; while Barus and Strouhal (*Bulletin of U. S. Geol. Survey*, No 14, p. 96), from a study of the viscous and electrical properties of hard and soft iron, have been led to think that hardness is due to heterogeneity of interior arrangement; hard temper being a condition in which the molecules are locked up into a new position of equilibrium, corresponding to a greater storage of potential energy than in the soft condition.

MEMOIR OF JOHN J. WEAVER.

The subject of this sketch was born in Philadelphia, on December 23, 1840, and received his education in the public schools of his native city, having been graduated from the Central High School in the class of 1860.

After several years of experience in commercial pursuits he became associated with Mr. J. S. Pennock, with whom he engaged in the plumbing business, under the firm name of Weaver & Pennock, a connection that was severed by his death on July 14, 1891, in his fifty-first year.

From the outset of his career, Mr. Weaver took a lively interest in every movement designed to extend educational advantages to young men, and he was conspicuously active and zealous in promoting the establishment of trades-schools and in planning and organizing the work of such schools in connection with several institutions and associations, with which he was prominently identified as a member and at times as an officer. To this good work, which with him was a labor of love, he devoted a large share of his time and services.

He was active in establishing the mechanical handiwork schools of the Spring Garden Institute in 1879 (said to have been the first manual training school, properly so-called, founded in the United States), and, to the success of this enterprise, which was due in great measure to his active interest therein as chairman of the committee, and to the large share of public attention it attracted, the subsequent formation of similar schools in connection with the public schools of the city and with Girard College may, we believe, not improperly, be ascribed.

Mr. Weaver was also instrumental in establishing the Trade-school for Plumbers, which was later merged in the trades-schools of the Master Builders' Exchange, of Philadelphia, in which institution he was prominent as an organizer and director.

Mr. Weaver became a member of the Franklin Institute in the year 1871, and from the first, exhibited a warm interest in its work. He was elected to the Board of Managers in 1880 and served acceptably in this capacity to the time of his death. One notable evidence of his activity, which, we believe, is destined to bear good fruit, is the fact that he introduced in the year 1887, a series of resolutions looking to the re-organization of the Institute, and the acquisition of another and larger building, with facilities for greatly increasing its capabilities for usefulness.

The outcome of this was the formation of a committee, of which he was an active member, that has devised some excellent plans, which, it is hoped will be realized at no distant day.

These are but a few of the many enterprises in which Mr. Weaver was actively interested, and which appear to be proper to notice in a memoir intended for the *Journal.*

It seems proper to refer also to his high appreciation of the duties of citizenship, and his warm interest in every movement designed to better the government of his native city.

The most notable traits of Mr. Weaver's character were the activity which he displayed in behalf of any cause in which his sympathies were enlisted; the zeal with which he advocated his views; and the courage with which he championed them in the face of opposition. His enthusiasm, however, was tempered with sound judgment, and was reinforced by a sturdy honesty of purpose, that never failed to command for him an attentive and respectful hearing, while his imperturbable good temper under defeat gained for him the hearty good-will of all who were his opponents in debate.

Mr. Weaver was a man of unusally robust physique, and his lamented death in the prime of his life and usefulness was a most unexpected event.

EDWIN J. HOUSTON,
STACY REEVES,
WM. H. WAHL.

PENNSYLVANIA STATE WEATHER SERVICE.

Announcement by the Committee on Meteorology.

The bill making an appropriation for continuing the State Weather Service having failed to become a law by reason of the objection of the Governor, the regular publication of the Monthly Bulletins in this *Journal* is interrupted.

As heretofore, the Monthly Bulletins will be carefully prepared for publication, at the central office and copies will be furnished to the Weather Bureau at Washington, to the Department of Internal Affairs at Harrisburg, as well as to each observer throughout the State.

It is confidently expected that the Hon. Secretary of Internal Affairs will print these Monthly Bulletins in his annual reports as heretofore, and it is hoped that they will also appear in the *Journal* as early as possible.

At any rate, it is designed to preserve the continuous series of observations.

The Committee, therefore, confidently appeals to the voluntary observers throughout the State to continue their patriotic and gratuitous services, with the assurance that they shall not be thrown away. W. P. TATHAM.

Chairman Committee on Meteorology of the Franklin Institute.

THE following letter received from the Chief of the Weather Bureau is self-explanatory:

WEATHER CROP BULLETIN
and
STATE WEATHER SERVICE DIVISION.

DEPARTMENT OF AGRICULTURE,
WEATHER BUREAU,
WASHINGTON CITY, July 21, 1891.

Mr. W. P. Tatham, Chairman Meteorological Committee Franklin Institute, Philadelphia, Penna.:

SIR.—I have the honor to inform you that the appointment of Mr. T. F. Townsend, Assistant Director of the Pennsylvania State Weather Service, to the position of Inspector in this Bureau, has made it necessary to relieve him from State Weather Service duties. Mr. L. M. Dey, observer in charge of the Philadelphia station, has been selected to succeed Mr. Townsend, and it is believed that his long experience in the general station work of this Bureau well qualifies him for that assignment.

He will at once consult with you relative to the work of the State Service, and plans for extending the same in the interests of agriculture in the State, and in this connection I would earnestly solicit a continuance of the co-operation of the Franklin Institute in that work, assuring you that I will do all in my power towards increasing the usefulness of that service.

I am, very respectfully,
MARK W. HARRINGTON,
Chief of the Weather Bureau.

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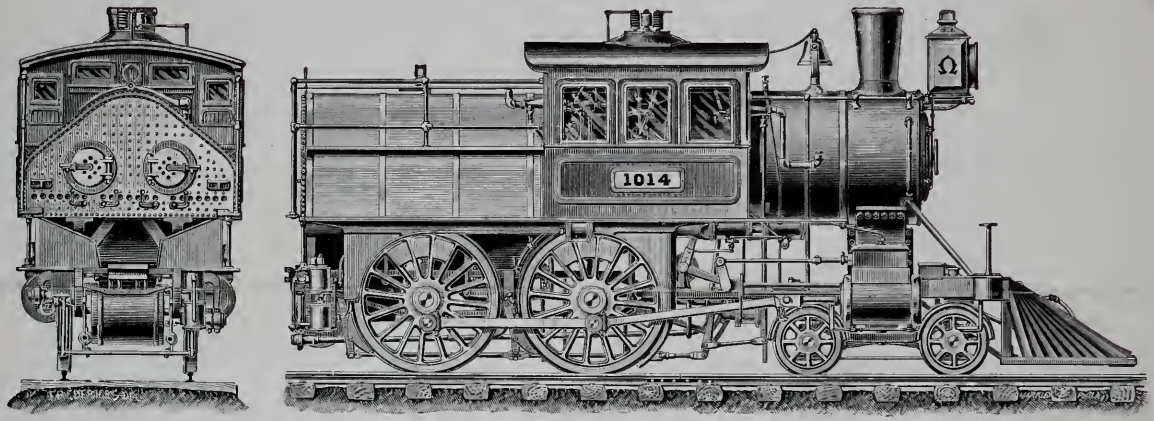
THE WOOTTEN BOILER.



JOURNAL

OF THE

FRANKLIN INSTITUTE

OF THE STATE OF PENNSYLVANIA.

FOR THE PROMOTION OF THE MECHANIC ARTS.

VOL. CXXXII. SEPTEMBER, 1891. No. 3

THE Franklin Institute is not responsible for the statements and opinions advanced by contributors to the *Journal*.

THE WOOTTEN LOCOMOTIVE.

[*Report of the Committee on Science and the Arts.*]

[No. 1,565.] HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, November 1, 1890.

The Sub-Committee of the Committee on Science and the Arts, constituted by the Franklin Institute of the State of Pennsylvania, to whom was referred, for examination and report,

THE WOOTTEN LOCOMOTIVE,

respectfully report that they have examined the working and illustrative drawings submitted to them, also the copies of the specifications of United States Letters-patent Nos. 192,725, 234,581, 291,126, 352,215, 354,370, 368,681, granted therefor, and the locomotive in use and at work and also those in course of construction, and find as follows:

The distinguishing features of these engines as compared with others is a much greater breadth of furnace and larger

area of grate with a less depth of fuel thereon, a change in the location of the cab from the rear of the engine and at the sides of the fire box to a position above the furnace, in some instances, and in others on each side of the waist of the boiler immediately in front of the fire box, the steam dome being located in the cab.

The construction of frames, driving wheels, cylinders and steam chests are not strikingly different from other well-known and usual types of engines.

This engine has been gradually developed into its present form and to give a fair and clear conception of its merits, a concise history of its development and causes leading to its invention appears to your committee as not inappropriate in this place.

At the outset, a demand, constantly increasing, for cheaper freights and diminished expense for motive-power in drawing trains, compelled the use of trains of greater capacity, so as to reduce the cost of wages relatively to the tonnage hauled. This necessitated more powerful engines, and whilst it was not difficult to increase the cylinder capacity or piston displacement of the engines, the limit of the boiler to supply adequate steam to such engines was soon reached.

The gauge of the railroad appeared to limit the width of the boilers admissible, the frames could not be spread any further apart, and under the practise of placing the furnace of the boiler between the frames, the only increase of grate surface practicable was in the direction of length. This rendered firing more difficult, and a deep bed of fuel was required to maintain steam pressure, the draught of air to maintain combustion demanded greater pressure on the exhaust, which could only be enforced by contracting the nozzle of the exhaust pipe and imposing a pressure upon the steam pistons during the return strokes. This, in view of the large piston surface recently coming into vogue, especially in compound locomotives, means a serious waste of force.

In addition to the above incentives to improvement, immense quantities of perfectly good coal, in dust and small grains, was steadily accumulating around every mine, and

whilst its value, when burned in a well-adapted furnace in a stationary engine, was a matter of daily demonstration, no long furnace or deep bed of such fuel was able to burn it upon a railway locomotive, and, moreover, a deep fire of such fuel would not burn, because the draft could not be forced through its entire surface, without much of the fuel being carried beyond reach with the then generally adopted furnaces.

The solution of this difficulty was found in an increased breadth of furnace—grate and fire box to accommodate it. Space to contain such boilers without interfering with the driving wheels was procured by placing the boiler above the driving wheels and frames, which were protected from ashes by a hopper-shaped ash pit.

The boiler then had broad expanses of nearly flat metallic external, as well as internal surfaces, having cross seams exposed to high internal pressure and required to be securely stayed or braced. The form of the plates presented oblique opposing surfaces, and stay bolts diagonal to such surfaces were applied to hold them together.

The oblique strain upon such stays, and the oblique intersections of the stays and plates, were subjected to shearing or diagonal strains, and the failure of such stays by breaking close to the plates, became a conspicuous objection to such structures.

An inspection of the cross and lengthwise sectional views of these earlier forms of the invention will serve to show the cause of this.

The remedy was found in changing the form of the furnace and the portion of the external shell of the boiler enclosing it so as to bring nearly parallel surfaces, formed of large plates without cross seams, opposed to each other. After this, the stays uniting them were subjected only to direct tensile strains and withstood them.

The fuel in such broad expanses of surface developed volumes of combustible gas, which burned with best effect when in large body or volume, but only imperfectly when subdivided by entering the flue tubes, so a combustion chamber was added.

The volume of draught usual with large fuel, when applied to fine or pulverulent fuel on a small grate surface, lifts and carries much of it mechanically from the furnace, but in the broad expanses of grate furnished in this boiler, the same volume passes through a lower velocity and with less pressure, so that instead of sweeping particles of fuel through the tubes with the products of combustion, the fine ash only appears to pass and deposit in a flocculent state in the smoke box and chimney.

The changes in form of the boiler, which we have thus far noted, are with reference to the combustion of fuel and generation of heat and durability of the boiler.

From experience it appeared desirable to place as much of the weight of the boiler as practicable lower down.

This was effected by the partition or bridge, excluding the fuel from the combustion chamber, in the shape of a dam, with the flue tubes and waist lower down in relation to the grate surface.

The combined effect of these improvements can best be understood by the report of the engine as worked upon the roads.

A sufficient proportion of the weight of the engine is placed upon the front truck wheels, serving to guide it securely upon the rails, whilst as large a proportion as is practicable is utilized in compelling adhesion between the driving wheels and the rails for purposes of propulsion.

A capacity for burning fuel, impracticable in furnaces of small grate area and large depth of fire bed, and an economy in quantity as well as quality of fuel required, ensued.

The several stages of improvement are set forth in the letters-patent, the drawings of which with a brief notice of their features are here stated.

The development of this invention, as it appears in the several letters-patent, is shown in the drawings reproduced from the patents and hereinafter briefly stated in chronological order.

In letters-patent 192,725, of July 3, 1877, the hopper-shaped ash pit and fire box extending sidewise over the rear driving wheels of one engine with six drivers and four

truck wheels is shown, the combustion chamber being over the middle driving-wheel axle, and included in a tapering part of the boiler uniting the fire box portion with the cylindrical waist. The claim of this patent is for a fire box wider than the distance between the wheels, and for the combustion chamber in combination with a bridge wall.

In letters-patent No. 254,581, of March 7, 1882, the ash pit is in the form of two rectangular funnels or hoppers, the grate is inclined from rear downwardly to the front, a flat crown sheet is used, stayed by parallel vertical stays to the outer curved shell, and the proportion of the combustion chamber in length to the furnace chamber is reduced.

In letters-patent 291,120, dated January 1, 1884, the forward part of the grate immediately in the rear of the bridge wall and across the entire width of the fire box is covered with fire brick to receive small particles of fuel which the draft through the grate would otherwise sweep over the bridge wall.

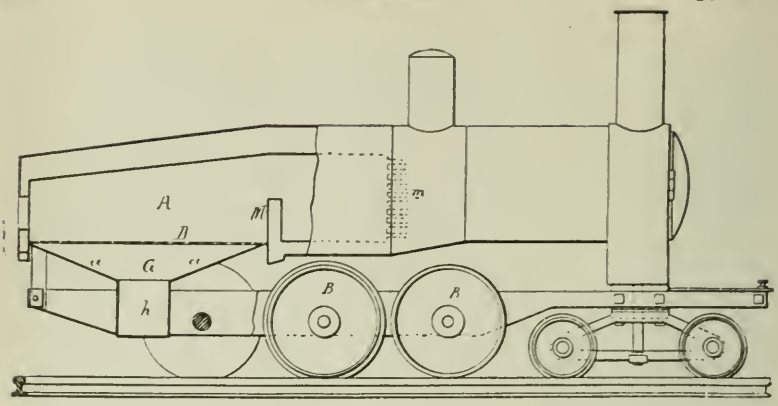
Patent No. 352,215, of November 9, 1886, shows an improved form of bridge wall which practically separates a combustion chamber within the fire box from the fuel supporting space on the grate.

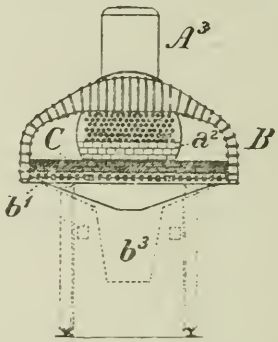
Patent No. 354,370, of December 14, 1886, is for a construction of boiler in which the rearward flue sheet of the furnace is without perforations, and acts as a bridge wall dispensing with the separate bridge walls in the preceding forms of this boiler.

Patent No. 361,661, of April 19, 1887, to J. F. Wootten and J. Snowden Bell, is for a form of this boiler in which a central partition or water wall is introduced in the furnace, making in effect two furnaces, with a bridge wall between the furnaces and the combustion chamber and flue.

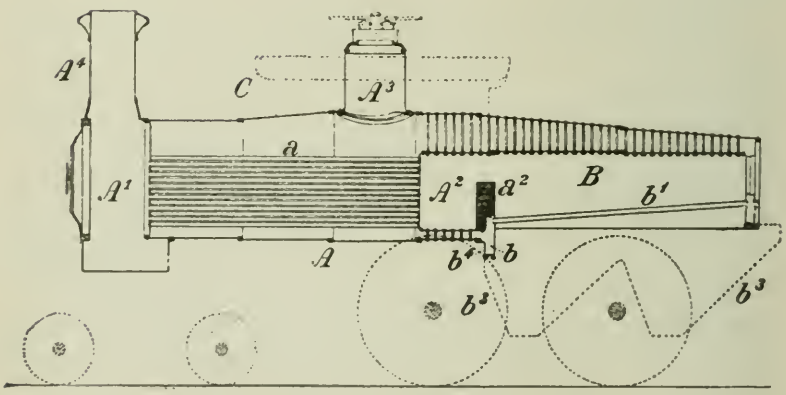
This construction offers the advantages of alternate firing, so that the gases from the fresh fuel in one furnace, can meet the intensely heated flames and products of combustion from the other furnace, and produce a better combustion.

The effect of these improvements, which it will be seen are in a continuous line of gradual development, are to produce a most efficient and serviceable boiler, capable of

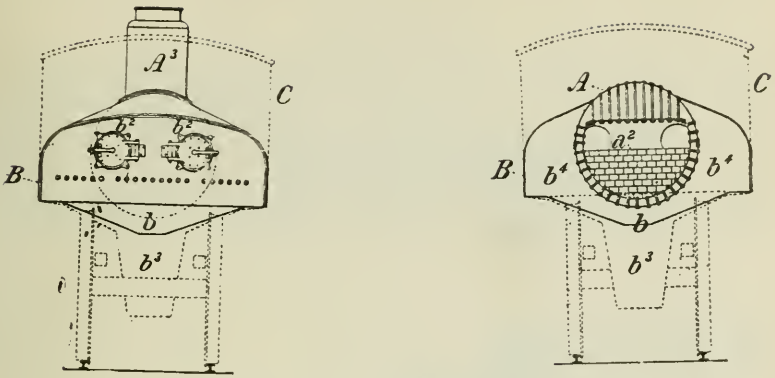




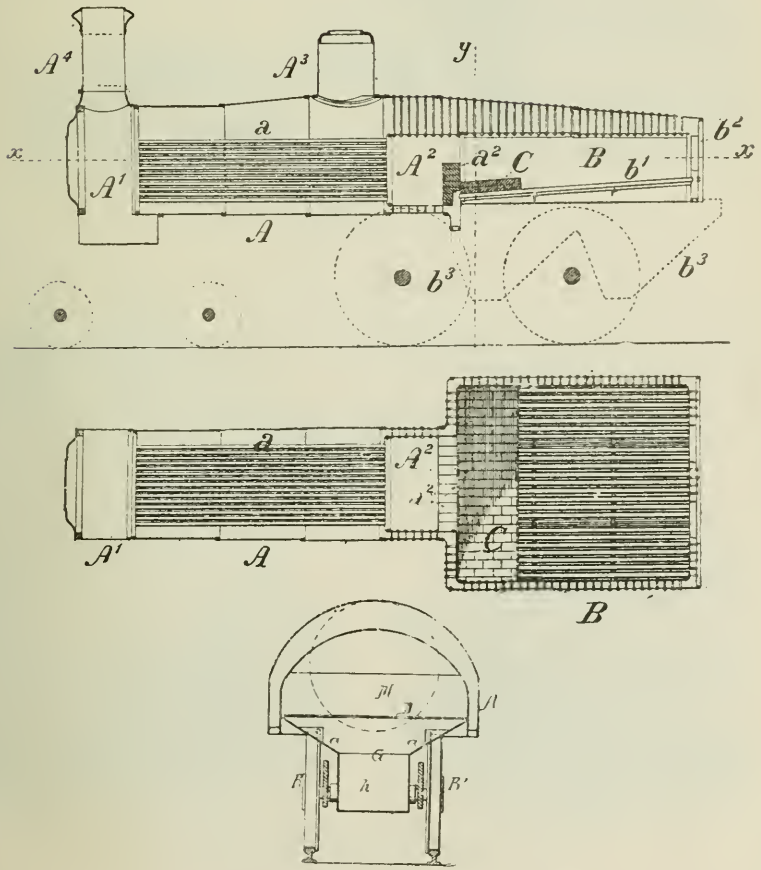
Patent No. 192,725, July 3, 1877.



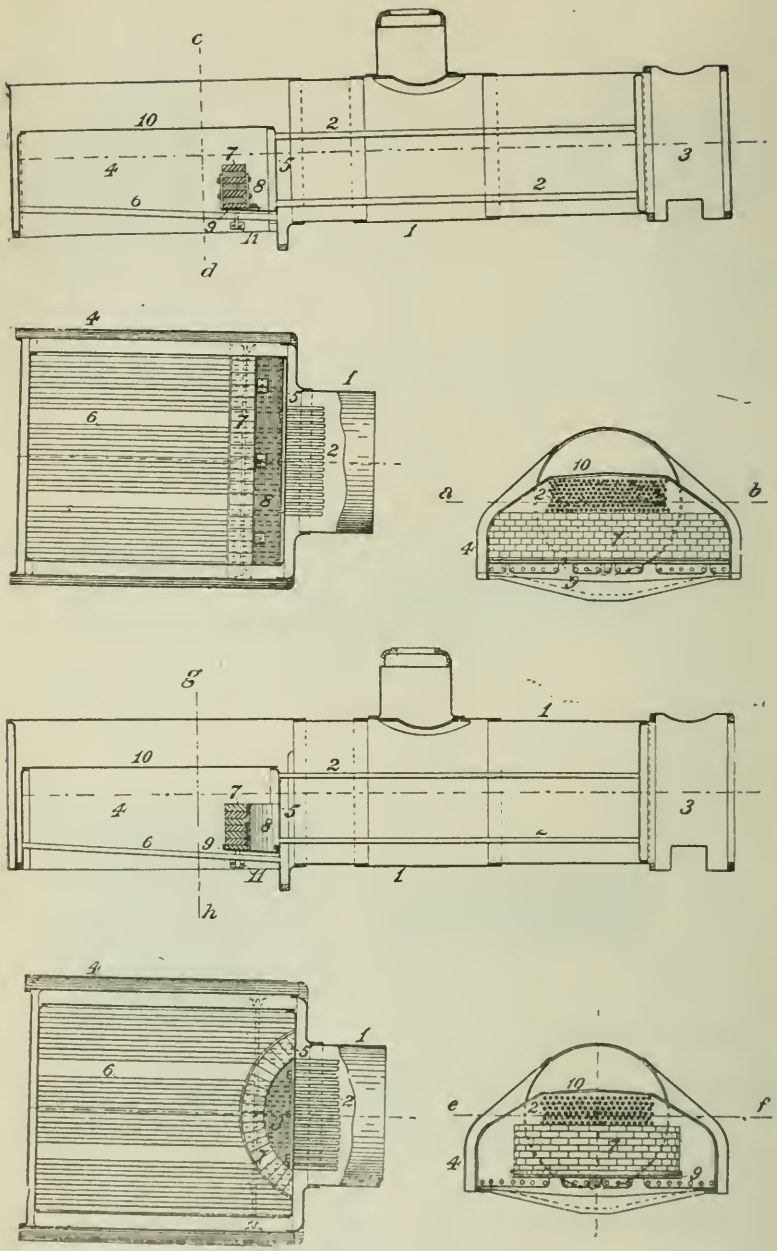
Patent No. 254,581, March 7, 1882.



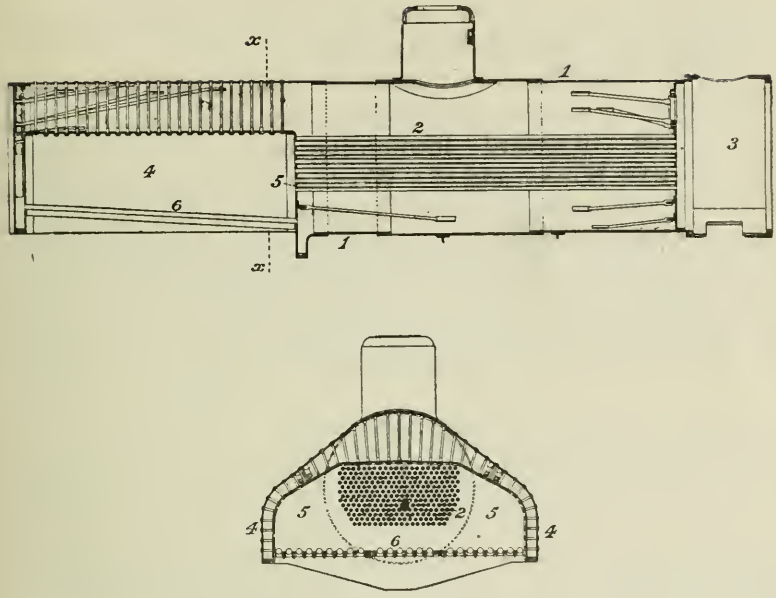
Patent No. 254,581, March 7, 1882.



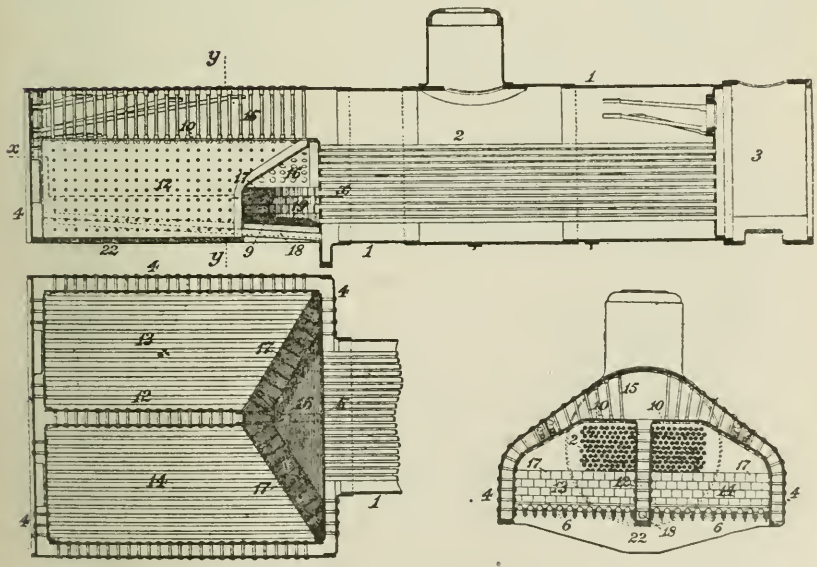
Patent No. 291,210, January 1, 1884.



Patent No. 352,215, November 9, 1886.



Patent No. 354,370, December 14, 1886.



Patent No. 361,661, April 19, 1887.

economically burning cheap grades of fuel inadmissible in other kinds of locomotive boilers.

Your committee in support of their conclusions quote the report of a series of tests made by Dr. Charles M. Cresson, of the "Standard" locomotive boiler of the Baldwin Locomotive Works, and of a Wootten boiler burning several kinds of fuel, which shows the claims for the capacity of the Wootten boiler as an efficient steam generator with different varieties of fuel, including some incapable of use in ordinary locomotives, to be fully sustained.

TABLE OF RESULTS OBTAINED FROM ANTHRACITE AND BITUMINOUS COALS IN THE WOOTTEN AND ORDINARY BOILERS.

Description of Coals.	*Total Heat Units in Fuel Used.*	*Heat Units Utilized in Generating Steam.*	*Total Equivalent in Pounds of Water Evaporated from 212° F.*	*Per Cent. of Total Heat Utilized.*	*Kind of Engine and Boiler.*
Anthracite, waste,	11,275	7,823	8·09	69·4	Frt. Consolidation Wootten boiler.
Anthracite, marketable,	11,913	7,813	8·08	65·5	Passenger. Wootten boiler.
Anthracite, marketable,	11,275	5,647	5·84	50·0	Passenger. Ordinary boiler.
Bituminous, waste,	12,764	8,209	8·49	64·3	Frt. Consolidation Wootten boiler.
Bituminous, marketable,	13,402	9,302	9·62	69·4	Frt. Consolidation Wootten boiler.
Bituminous, marketable,	13,402	7,397	7·65	55·2	Frt. Consolida'n Ordinary boiler.
Bituminous, marketable,	13,363	9,138	9·45	68·3	Passenger. Wootten boiler.
Bituminous, marketable,	13,731	7,416	7·67	54·0	Passenger. Ordinary boiler.
Lignite, 20 per cent. water,	7,871	3,316	3·43	42·1	Frt. Consolidation Wootten boiler.

VALUES OF THE VARIOUS FUELS USED.

The total heat given out by samples of the fuel used in these trials, when burned in oxygen, expressed in pounds of water evaporated from 212° F., is as follows:

	Pounds.
Waste anthracite coal,	11·66
Marketable anthr cite coal,	12·98
Waste bituminous coal,	13·20
Marketable bituminous coal,	14·86
Marketable semi-bituminous coal,	13·86
Lignite (20 per cent. water),	8·41

PERCENTAGE OF THE VALUES OF THE COALS OBTAINED FROM TWO BOILERS.

The results obtained in the ordinary locomotive boiler, yielded for steam generation from—

	Per Cent.
Anthracite coal,	50·0
Bituminous coal,	54·0
Semi-bituminous coal,	55·2

of the total heat obtainable from the fuel; and the results obtained from the Wootten boiler, which is adapted to burn waste coal, yielded for steam generation with—

	Per Cent.
Anthracite waste,	69·4
Marketable anthracite,	65·5
Bituminous waste,	64·3
Bituminous lump,	68·3

of the total heat obtainable from the fuel.

The data from which the work done by these fuels is derived were obtained from the results of continuous daily operations, of such magnitude as to remove them from the category of experiment and place them upon the footing of practical operations.

An appendix* to this report contains copies of the specifications and drawings of the several letters-patent and illustrations of the engines as in use, together with details of their dimensions, etc., and reports of tests.

In view of the excellent results demonstrated by invention under tests, fully confirmed by several years of practical use, your committee consider it proper to recommend the award to John E. Wootten, of the John Scott Legacy Premium and Medal.

S. Lloyd Wiegand, *Chairman*,
Samuel F. Prince, Jr.,
Luther L. Cheney,
John E. Codman,

Adopted December 3, 1890.

H. R. Heyl,
Chairman (pro tem.) of Committee on Science and the Arts.

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* Not published, but accessible on application to the Secretary.

EYESIGHT: ITS CARE DURING INFANCY AND YOUTH.

By L. Webster Fox, M. D.

[*A lecture delivered before the Franklin Institute, December 5, 1890.*]

The lecturer was introduced by Prof. Edwin J. Houston, and spoke as follows:

Members of the Institute, Ladies and Gentlemen:

Medical science, as taught in our medical colleges to-day, has two objects in view: (1) the prevention of disease; (2) the amelioration of disease and its cure. Some of our advanced thinkers are suggesting a new mode of practice; that is, the prevention of disease by proper hygienic measures. Chairs are being established and professors appointed to deliver lectures on hygiene. Of what value is the application of therapeutics if the human economy is so lowered in its vital forces that dissolution is inevitable. Is it not better to prevent disease than to try the cure after it has become established, or has honey-combed the constitution?

These few preliminary remarks are *apropos* to what is to follow in the subject which I have selected as the topic for discussion this evening.

Vision is the most useful of all the senses. It is the one gift which we should cherish and guard the most. And at no time in one's life is it more precious than in infancy and youth.

In infancy, when the child is developing, the one great avenue to the unfolding, or more properly speaking, the development, of the intellect is through the eye. The eye at this period holds in abeyance all the other senses. The child, when insensible to touch, taste, smell or hearing, will become aroused to action by a bright light or bright colors, or the movement of any illuminated object, proving to all that light is essential to the development of the first and most important sense. Again, the infant of but six days

of age will recognize a candle flame, while its second sense and second in importance to its development—hearing—will not be recognized for *six* weeks to two months. Taste, touch and smell follow in regular sequence. Inasmuch as light makes thus early an impression on the delicate organ of vision how necessary it behooves us to guard the infant from too bright lights or too much exposure in our bright climate. Mothers—not only the young mother with her first child—but also those who have had several children, are too apt to try to quiet a restless child by placing it near a bright flame; much evil to the future use of those eyes is the outgrowth of such a pernicious habit. Light throws into action certain cells of that wonderful structure of the eye, the retina, and an over-stimulus perverts the action of those cells. The result is that by this over-stimulation the seeds of future trouble are sown. Let the adult gaze upon the arc of an electric light or into the sun, and for many moments, nay hours, that individual has dancing before his vision scintillations and phosphenes. His direct vision becomes blurred, and, as in the case of a certain individual I have in mind, there may be a permanent loss of sight. Parents should take the first precaution in the child's life, and not expose it to a light too bright or glaring. When in the open air let the child's eyes be protected from the direct rays of the sun. While it is impossible to give all children the advantage of green fields and out-door ramblings, yet nature never intended that civilization should debar the innocent child from such surroundings.

An anecdote is related of a French ophthalmic surgeon, that a distinguished patient applied to him for relief from a visual defect; the surgeon advised him to go into the country and look out upon the green fields: the green color with its soothing effect soon brought about a restoration of vision. What I wish to illustrate by this anecdote is that children should be allowed the green fields as their best friend in early life, it tones up the system and rests the eye. After out-door exercise and plenty of it, we should turn our attention to the home surroundings of our little ones. The over-heated rooms of the average American

home I am sure have more to do with the growing tendency of weak eyes than we feel like admitting. Look at these frail hot-house plants and can anyone believe that such bodies nourished in almost pestilential atmosphere can nourish such delicate organs of vision, and keep them ready for the enormous amount of work each little eye performs daily. The brain developing so rapidly wills with an increasing rapidity the eye to do increasing duties—note the result—a tendency to impoverished circulation first, and the eye with its power to give the brain a new picture in an infinitesimal short space of time means lightning-like circulation—the eye must give way by its own exhaustion.

Civilization is the progenitor of many eye diseases.

After a boy has grown to that age when it becomes necessary for him to begin the education prescribed by the wise men, obstacles are placed in his way to aid again in causing deterioration of vision. It is not so much the overcrowded condition of our school-rooms as the enormous amount of work, that causes deterioration of sight. Our children begin their school-life at a time when they are too young. A child at six years of age who is forced to study all day or even a part of a day will not run the same race that one will who commences his studies at ten—all things being equal. The law prescribes that so much time must be devoted to study, so many forms must be passed, so many books must be read, so many pages of composition written—all probably in badly-lighted rooms, or by artificial light. Note the effect. First, possibly, distant vision gives way; the teacher, sympathizing with the over-burdened child, tries to make the burden lighter by changing his position in the room or placing him under the cross-light from a window; as the evil progresses the child is taken to an ophthalmic surgeon and the inevitable result—glasses—rightly called "crutches for the eyes" are given. What would be thought of a cause which would weaken the legs of that boy so that he would have to use crutches to carry him through life? If civilization be responsible for an evil, let our efforts be put forth in finding a remedy for that evil.

A discussion, in a recent number of the *British Medical*

Journal,* on "The Claims and Limitations of Physical Education in Schools," has many valuable hints which should be followed by educators in this country. Dr. Carter, in the leading paper on this subject, makes the pregnant remark, "If the hope is entertained of building up a science of education, the medical profession must combine with the profession of teaching, in order to direct investigation and to collect material essential to generalization. Without such co-operation educational workers must continue to flounder in the morasses of empiricism, and be content to purchase relative safety at the cost of slow progress, or no progress at all." In other words, an advisory medical board should co-exist with our board of public education, to try to hold in check or prevent a further "cruelty in trying to be kind." Private institutions of education recognize the importance of physical training and development, and in such institutions the deterioration of vision is in proportion, less than in institutions where physical training is not considered. In one school of over 200 middle class girls, Dr. Carter found that, during a period of six years, no fewer than ten per cent. of the total number of girls admitted during that time, have been compelled to take one or more terms' leave of absence, and of the present number twenty-eight per cent. have medical certificates exempting them from gymnastic exercise and 10·25 per cent. of the total present number wear eye-glasses of some kind or other. From my own experience the same number of students in our schools would show about the same percentage of visual defects. These questions are of such growing importance that not only instructors, but the medical fraternity should not rest until these evils are eradicated.

Dr. J. W. Ballantyne, of Edinburgh, in a lecture† on diseases of infancy and childhood, says: "The education of the young people of a nation is to that nation a subject of vital importance." The same writer quotes the startling statement made by Prof. Pflüger, that of 45,000 children

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* Nov. 1, 1890.

† *Lancet*, Nov. 1, 1890.

examined in Germany more than one-half were suffering from defective eyesight, while in some schools the proportion of the short-sighted was seventy or eighty per cent., and, crowning all, was the Heidelberg Gymnasium, with 100 per cent. These figures, the result of a careful examination, are simply startling, and almost make one feel that 'twere better to return to the old Greek method of teaching by word of mouth.

Prof. Pflüger attributes this large amount of bad sight to insufficient lighting of school-rooms, badly printed books, etc. One must agree with a certain writer, who says: "Schools are absolute manufactories of the short-sighted, a variety of the human race which has been created within historic time, and which has enormously increased in number during the present century." Granting that many predisposing causes of defective vision cannot be eliminated from the rules laid down by our city fathers in acquiring an education, it would be well if the architects of school buildings would bear in mind that light when admitted into class-rooms should not fall directly into the faces of children, but desks should be so arranged that the light must be sufficiently strong and fall upon the desk from the left hand side. My attention has repeatedly been called to the cross lights in a school-room. The light falling directly into the eyes contracts the pupil which is already contracted by the action of the muscle of accommodation in its effort to give a clearer picture to the brain. This has a tendency to elongate the eye-ball, and as a permanent result we have near-sightedness. Where the eye-ball has an unnatural shortness this same action manifests itself by headaches, chorea, nausea, dyspepsia, and ultimately a prematurely breaking-down of health. The first symptom of failing sight is a hyper-secretion of tears, burning of the eye-lids, loss of eye-lashes, and congestion either of the eye-lids or the eye-ball proper.

The natural condition of aboriginal man is far-sighted. His wild life, his nomadic nature, his seeking for game, his watching for enemies, his abstention from continued near work, have given him this protection. Humboldt speaks of

the wonderful distant vision of the South American Indians; another traveller in Russia of the power of vision one of his guides possessed, who could see the rings of Saturn. My recent examinations among Indian children of both sexes also confirm this. While the comparison is not quite admissible, yet the recent investigations carried on by Lang and Barrett, who examined the eyes of certain mammalia, found that the larger number were hypermetropic or far-sighted. With all the difficulties which naturally surround such an examination they found that in fifty-two eyes of rabbits, thirty-six were hypermetropic and astigmatic, eight were hypermetropic only, five were myopic and astigmatic, and others presented mixed astigmatism. In the eyes of the guinea pig about the same proportion of hypermetropia existed. The eyes of five rats examined gave the following result: Some were far-sighted, others were hypermetropic and astigmatic, one was slightly myopic and one had mixed astigmatism. Of six cows, five were hypermetropic and astigmatic and one was slightly myopic.

Six horses were also examined, of which one had normal sight, three were hypermetropic and astigmatic, and two had a slight degree of astigmatism. They also examined other animals and the same proportion of hypermetropia existed. These gentlemen found that as an optical instrument the eye of the horse, cow, cat and rabbit, is superior to that of the rat, mouse and guinea pig.

I have for the last five years devoted considerable attention to the vision of the Indian children who are pupils at two institutions in this city. I have at various times made careful records of each individual pupil and have from time to time compared them. Up to the present there is a growing tendency towards myopia or short-sightedness, *i. e.*, more pupils from year to year require near-sighted glasses. The natural condition of their eyes is far-sighted and the demands upon them are producing many nervous or reflex symptoms, pain over the frontal region and headaches. A good illustration of the later trouble is showing itself in a young Indian boy, who is at present undergoing an examination of his vision as a probable cause for his

headaches. This boy is studying music; one year ago he practised two hours daily on the piano and studied from three to five hours besides. This year his work has been increased; he is now troubled with severe headaches, and after continued near work for some time letters become blurred and run together. This boy is far-sighted and astigmatic; glasses will correct his defect, and it will be interesting to note whether his eyes will eventually grow into a near-sighted one. I have several cases where the defective vision has been due entirely to other causes, such as inflammation of the cornea, weakening this part of the eye, and the effect in trying to see producing an elongation of the anterior portion of the eyeball, and this in turn producing myopia. The eye of the Indian does not differ materially from that of any deeply pigmented race. The eyeball is smaller than in the Caucasian, but when we examine the interior we find the same distribution of the blood-vessels and same shape of the optic nerves. The pigment deposit in the choroid is excessive and gives, as a background to the retina, a beautiful silvery sheen when examined with the ophthalmoscope. One thing which I noticed particularly was the absence of this excessive deposit of pigment and absence of this watered-silk appearance in the half-breeds, they taking after the white race.

The absence of many of the intraocular diseases common among the white children were also absent, especially those diseases which are the result of near work.

It is a well-known fact among breeders of animals, that where animals are too highly or finely bred the eye is the organ first to show a retrogression from the normal. In an examination by myself some years ago among deaf mutes, I found the offspring of consanguineous marriages much affected and while not only were many afflicted with inflammatory conditions of the choroid and retina; their average vision was much below the normal.

My quoting Messrs. Lang and Barrett's figures was to bring more prominently to the notice of my hearers the fact that the eyes of primitive man resembled the eyes of the lower mammalia and that the natural eye as an organ of vision was

hypermetropic, or far-sighted, and that civilization was the cause of the myopic or near-sighted eye. Nature always compensates in some way. I grant that the present demands of civilization could not be filled by the far-sighted eye but the evil which is the outgrowth of present demands does not stop when we have reached the normal eye, but the cause once excited, the coats of this eye continue to give way and myopia or a near-sighted condition is the result.

Among 300 Indians examined, I found when I got to the Creeks, a tribe which has been semi-civilized for many years, myopia to be the prevailing visual defect.

Without going into statistics I am convinced from my experience that the State must look into this subject and give our public school system of education more attention, or we as a people will soon be known as a "spectacled race."

Myopia or short-sightedness among the Germans is growing at a tremendous rate. While I do not believe that the German children perform more work than our own children, there is one cause for this defect which has never been touched upon by writers, and that is the shape of the head. The broad flat face or German type, as I would call it, has not the deep orbit of the more narrow, sharp-featured face of the American type. The eye of the German standing out more prominently and in consequence less protected, is thereby more prone to grow into a near-sighted eye. One of the significant results of hard study was recently brought to my notice by looking over the statistics on the schools of Munich in 1889. In those schools 2,327 children suffered from defective sight, 996 boys and 1,331 girls,

Of 1,000 boys, in the first or elementary class, 36 are short-sighted; in the second, 49; in the third, 70; in the fourth, 94; in the fifth, 108; in the sixth, 104; and in the last and seventh, 108. The number of short-sighted boys, therefore, from the first class to the seventh, increases about threefold. In the case of the girls, the increase is from 37 to 119.

These statistics in themselves show us the effects of overwork, incessant reading or study by defective gas- or lamp-light, or from an over-stimulating light, as the arc light,

late hours, dissipation and frequent rubbing of the eye, also fatigue, sudden changes from darkness to light, and what is probably worse than all, reading on railway trains. The constant oscillations of the car cause an over-activity of the muscle of accommodation which soon becomes exhausted, the brain willing the eye to give it a clear photograph continues to force the ciliary muscle, which muscle governs the accommodation, in renewed activity, and the result may easily be foretold.

The fond parents finding that the vitiated air of the city is making their once rosy-cheeked children turn pale, seek a remedy in the fresh air of the country; the children find their way to city schools; this necessitates travelling so many miles a day in railway cars; the children take this opportunity of preparing their studies while en route to the city, and here is where they get their first eye-strain. Children have the example set them by their parents or business men who read the daily papers on the trains. Children are great imitators, and when their attention is called to the evil, quote their parents' example and they follow it. No wonder each generation is growing more effeminated.

The light in sick rooms should never fall directly on the eyes, nor should the rooms be either too dark or too light.

The Esquimaux and Indians long ago noted the fact that sunlight reflected from freshly-fallen snow would soon cause blindness.

The natives of Northern Africa blacken themselves around the eyes to prevent ophthalmia from the glare of the hot sand. In Fiji, the natives when they go fishing blacken their faces. My friend, Dr. Bartelott, presented me with a pair of eye protectors which he brought from Alaska. The natives use them to protect themselves from snow-blindness. These snow spectacles, or snow eyes, as they are called, are usually made out of pine wood which is washed upon their shores, drift-wood, from southern climes.

The posterior surface is deeply excavated to prevent its

obstructing the free motion of the eye-lids, on each side a notch is cut at the lower margin to allow a free passage for the tears. The upper margin of the front surface is more prominent than the under to act as a shade to the eyes. The inner surface is blackened to absorb the excessive light. The openings are horizontal slits. The eyes are thus protected from the dazzling effect of the light.

My friend Dr. Grady, of Omaha, communicated to me a history of three hunters who almost lost their eyesight by too long exposure to the bright rays of the sun falling on snow.

The abuse of tobacco leads to impairment of vision in the growing youth. Cigarette smoking is an evil. I am inclined to believe that the poisons inhaled arrest the growth of boys; surely it prevents a mental development, and when carried to excess affects vision more by lessening the power of nerve conduction, than acting directly on the eye.

It is not the one cigarette which the boy smokes that does the harm, but it is the one, two or three packages smoked daily. This excessive smoking thoroughly perverts all the functions which should be at their best to aid this growing youth. First we have failing digestion, restless nights, suspension of growth, lack of mental development, the loss of nerve tone, loss of the power of accommodation in vision, failing sight, headaches, enfeeblement of the heart. Let a man who is a habitual smoker of cigars attempt to smoke even one package of cigarettes and he will complain of nausea, dry throat and loss of appetite. If a strong man is so much affected by this poison, how much less can a boy resist the inroads of such poisons. In Germany the law forbids the sale of cigarettes to growing boys. New York State has a similar law, and why should our own or any other State be behind in passing prohibitory laws against this evil; and this is a growing evil.

I have never seen a case of tobacco amblyopia in boyhood, but such a condition is not infrequent in adults. In boys the action of nicotine acts especially upon the heart, the impulse is rendered weaker and intermittent and many

young boys lay the seeds of organic disease which sooner or later culminates fatally. Boys should be prohibited from smoking, first by their parents, second by law, but not such laws whose enforcement is a failure, third by placing a heavy fine upon dealers who sell to minors. The pernicious evil of intoxication is no less an evil upon the nervous system of a youth than is the habit of cigarette smoking, but fortunately this habit is less common. Having traced from aboriginal man to the present civilized individual the cause of his myopia, what must we do to prevent a further deterioration of vision? Unfortunately, the physician of our country is not, as I am told, like the Japanese physician. Our medical men are called to attend people who are ill and to try to get them well—the Japanese physician is paid only to keep his patients in health.

The first effort parents should make is to see that their children have plenty of out-door exercise. Good warm clothing in winter and light-texture cloth in summer. A great difference of opinion exists as to the age at which a child should begin its studies. I feel sure that the boy who commences his studies at ten will far outrun the one who commences study at six. Every child should commence his lessons in the best kindergarten, the nursery. Let object lessons be his primer—let him be taught by word of mouth —then, when his brain is what it should be for a boy of ten, his eyes will be the better able to bear the fatigue of the burdens which will be forced upon him. Listen to what Milton has left on record as a warning to those young boys or girls who insist upon reading or studying at night with bad illumination.

"My father destined me, from a child, for the pursuits of polite learning, which I prosecuted with such eagerness that, after I was twelve years old, I rarely retired to bed, from my lucubrations, till midnight. This was the first thing which proved pernicious to my eyes, to the natural weakness of which were added frequent headaches." Milton went blind when comparatively a young man, and it was always to him a great grief. Galileo, the great astronomer, also went blind by overwork. It was written of him, "The

noblest eye which ever nature made is darkened—an eye so privileged, and gifted with such rare powers, that it may truly be said to have seen more than the eyes of all that are gone, and to have opened the eyes of all that are to come."

When the defect of far-sightedness or near-sightedness exists, we have but one recourse—*spectacles.*

Some time ago I published, in the *Medical and Surgical Reporter*, an article on the history of spectacles. The wide-spread interest which this paper created has stimulated me to continue the research and since this article appeared I have been able to gather other additional historical data to what has been described as an invention for "poor old men when their sight grows weak."

The late Wendell Phillips, in his lecture on the "Lost Arts," speaks of the ancients having magnifying glasses. "Cicero said that he had seen the entire *Iliad*, which is a poem as large as the New Testament, written on a skin so that it could be rolled up in the compass of a nut-shell;" it would have been impossible either to have written this, or to have read it, without the aid of a magnifying glass.

In Parma, a ring 2,000 years old, is shown which once belonged to Michael Angelo. On the stone is engraved the figures of seven women. You must have the aid of a glass in order to distinguish the forms at all. Another *intaglio* is spoken of—the figure is that of the god Hercules; by the aid of glasses, you can distinguish the interlacing muscles and count every separate hair on the eyebrows." Mr. Phillips again speaks of a stone 20 inches long and 10 wide containing a whole treatise on mathematics, which would be perfectly illegible without glasses. Now, our author says, if we are unable to read and see these minute details without glasses, you may suppose the men who did the engraving had pretty strong spectacles.

"The Emperor Nero, who was short-sighted, occupied the imperial box at the Coliseum, and, to look down into the arena, a space covering six acres, the area of the Coliseum, was obliged, as Pliny says, to look through a ring with a gem in it—no doubt a concave glass—to see more clearly the sword play of the gladiators. Again, we read of

Mauritius, who stood on the promontory of his island and could sweep over the sea with an optical instrument to watch the ships of the enemy. This tells us that the telescope is not a modern invention."

Lord Kingsborough, speaking of the ancient Mexicans, says: "They were acquainted with many scientific instruments of strange invention, whether the telescope may not have been of the number is uncertain, but the thirteenth plate of *Dupaix's Monuments*, part second, which represents a man holding something of a similar nature to his eye, affords reason to suppose that they knew how to improve the powers of vision."

*Our first positive knowledge of spectacles is gathered from the writings of Roger Bacon, who died in 1292. Bacon says: "This instrument (a plano-convex glass or large segment of a sphere) is useful to old men and to those who have weak eyes; for they may see the smallest letters sufficiently magnified."

Alexander de Spina, who died in 1313, had a pair of spectacles made for himself by an optician who had the secret of their invention. De Spina was so much pleased with them that he made the invention public.

Monsieur Spoon fixes the date of the invention between 1280 and 1311. In a manuscript written in 1299 by Pissazzo, the author says: "I find myself so pressed by age that I can neither read nor write without those glasses they call spectacles, lately invented, to the great advantage of poor old men when their sight grows weak." Friar Jordan, who died in Pisa in 1311, says in one of his sermons, which was published in 1305: "That it is not twenty years since the art of making spectacles was found out, and is indeed one of the best and most necessary inventions in the world." In the fourteenth century spectacles were not uncommon and Italy excelled in their manufacture. From Italy the art was carried into Holland, then to Nuremberg, Germany. In a church in Florence is a fresco representing St. Jerome (1480). Among the several things represented is an ink-

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* *Med. and Surg. Reporter.*

horn, pair of scissors, etc. We also find a pair of spectacles, or *pince-nez*—the glasses are large and round and framed in bone.

It was not until 1575 that Maurolicus of Messina pointed out the cause of near-sightedness and far-sightedness and explained how concave glasses corrected the former, and convex glasses the latter defect.

In the wake of advanced education stalks the spectacle age. Any one watching a passing crowd cannot fail but note the great number of people wearing spectacles. Unfortunately it is not limited to adults, but our youths of both sexes go to make up this army of ametropes.

At what age should children first wear glasses? This is a much debatable question. Where there is simply a defect of vision I should never prescribe a pair of glasses for a child under ten years of age. A child under this age runs many risks of injury to the eyeball by accident to the glasses, and to cut the eye with glass is a very serious affair. Rather let a child go without study, or even with impaired vision, than run the risk of a permanent loss of sight.

Another source of evil I must call your attention to, and that is the indiscriminate use of glasses given by itinerant vendors of spectacles who claim a thorough knowledge of the eye, who make examination free, but charge double price for glasses.

Persons, before submitting themselves into the hands of opticians, should know that they are not suffering from any incipient disease of their eyes. I do not, for a moment, claim that a practical optician cannot give you a pair of glasses which will make you see—he does nothing more than hand you a number of pairs of glasses and you select the one pair which you think answers the purpose. How can any one but a medical man know that the impairment of vision does not arise from diminished sensibility of the retina? If so, the glasses just purchased, which may be comfortable for a time, may cause an irreparable loss of vision. Every ophthalmic surgeon will tell you that he has had a number of such cases. Do not be misguided by purchasing cheap spectacles. Glasses advertised as having

"remarkable qualities" are always to be passed by. They have "remarkable qualities;" they always leave the person wearing them worse at the end of a few months. Whenever an eye finds relief in a shaded or colored glass, something is going wrong with the interior of that eye. Seek advice, but do not trust the eyes of yourself, much less those of your children, in the hands of the opticians who advertise their examinations free.

Such individuals should be brought before a tribunal, and the matter sifted as to whether the sense of sight is less to be taken care of than if that same patient were ill with pneumonia and a druggist were to prescribe remedies which might or might not aid this patient. If one man must comply with the law, why should not the other? Our medical colleges are lengthening the course of studies; the advances in the various departments of science demand this. It is by the aid of the ophthalmoscope that many obscure diseases are diagnosed, and while it is impossible for every young man who obtains a diploma to become thoroughly proficient in the use of this instrument, yet the eye shows to him many conditions which guide him to the road of successful treatment. Think of a case of optic neuritis—inflammation of the optic nerve—going to an optician and fitting one set of glasses after another until the patient suddenly discovers that blindness is inevitable. Many individuals, and very intelligent ones at that, think that so long as a glass makes them see, that is all they need. When we know that scarcely two eyes are alike, we can at once feel that it is very important that each eye should be properly adjusted for a glass; by this we are sure of having comfort in reading and preserving vision.

There is a very important defect in vision which should be detected as early in life as possible, and that is color-blindness. The boy who is a color-blind will always remain a color-blind, and as forty in every 1,000 of the male sex are color-blind, it is essential that they know their defect, and train their course accordingly. It would be to the advantage of all boys to undergo such an examination once in their school-life; a color-blind would be useless where

the selection of color entered into his life-work. If a boy had a talent for drawing or engraving, and were color-blind he would make a success of his life, whereas if he would attempt to mix paints of different colors he would be a failure.

I shall not dwell upon the scientific part of color-blindness, nor discuss either the Young-Helmholtz or the Hering theories of color defect, but shall deal with its practical use in every-day life.

Until the year 1853, very little was known about color-blindness, and much less written about it.

Dr. George Wilson, in 1853, wrote several articles, which were published in the *Edinburgh Monthly Journal of Medical Science*. These articles created such an interest in the scientific world that Dr. Wilson brought out a book, entitled *Researches on Color-Blindness*, two years later. So thoroughly did Dr. Wilson sift this subject that no writer up to the present day has added anything practical to what was then known.

Dr. Wilson writes in his preface: "The most practical relation of color-blindness is that which it has to railway and ship signals. He further states: "The professions for which color-blindness most seriously disqualifies are those of the sailor and railway servant who have daily to peril human life and property on the indication which a colored flag or a lamp seems to give."

Dr. Bickerton, in an article on this same subject, speaking of the careless way in which lights were used on ships at sea, says: "Until the year 1852, there were no definite rules regarding the carrying of lights at night by vessels at sea. * * * At this time the subject of color-blindness had not awakened the attention of practical observers, and had the fact been known that between three and four per cent. of the whole male population are color-blind, some other mode might have been devised to indicate the positions of vessels at night than by showing red and green lights.

If it is so very important to have sailors with good color perception, where, at least, four men are on the lookout,

how much more important is it to have our engine drivers with perfect color perception, where one man alone watches the signal of safety or danger. The growth of our railway system is constantly increasing. We have to-day probably 150,000 men employed in this service. The boys attending public schools to-day in a few years will have to fill the ranks of these men. How important for these boys to know that they have not this defect. If the forty boys in every 1,000 are found, what is to be done with them? The engraver, the wood-cut engraver, the etcher, all wish apprentices. I am also informed that these occupations pay well. It requires talent to fill them, and here is an opening for the color-blind. Hear what a color-blind writes:* "I beg to offer some particulars of my own case, trusting it may be of use to you. I am an engraver, and, strange as it may appear, my defective vision is, to a certain extent, a useful and valuable quality. Thus, an engraver has two negative colors to deal with, *i. e.*, white and black. Now, when I look at a picture, I see it only in white and black, or light and shade, and any want of harmony in the coloring of a picture is immediately made manifest by a corresponding discord in the arrangement of its light and shade or as artists term it, the *effect*. I find at times, many of my brother-engravers in doubt how to translate certain colors of pictures, which to me are matters of decided certainty and ease. Thus, to me it is valuable." Having already spoken about the importance of having all boys undergo an examination for color-blindness once in their school-lives, we have two very good reasons for making this suggestion.

First, prevent a boy following a trade or occupation where he is incapacitated, and, secondly, let him be trained for a certain trade or occupation when the defect exists. The savage races possess the perception of color to a greater degree than do civilized races. I have just concluded an examination of 250 Indian children; 100 were boys. Had I selected 100 white boys from various parts of the United States I would have found at least five color-blinds; among

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* Wilson, p. 27.

the Indian boys I did not find a single one. Some years ago I examined 250 Indian boys and found two color-blind, a very low percentage when compared with the whites. Among the Indian girls I did not find any. When we know that only two females in every 1,000 among whites are color-blind, it is not surprising that I did not find any examples among the Indian girls.

The usual tests for color-blindness are the matching of wools; the common error the color-blind falls into is matching a bright scarlet with a green. On one occasion, a color-blind gentleman found fault with his wife for wearing, as he thought, a bright scarlet dress, when in point of fact, she was wearing a bright green. Another color-blind who was very fond of drawing, once painted a red tree in a landscape without being aware that he had done so.

Among the whites it affects all classes. It is found as relatively common among the intelligent as the illiterate, and unfortunately, up to the present, we have not discovered any remedy for this defect.

Without quoting many instances where a color-blind man was responsible for accidents at sea, I must quote a case where an officer on the watch issued an order to "port" his vessel, which, if his order had been carried out, would have caused a collision, and a probable serious loss of life.

The letter was written by Capt. Coburn, and is to be found in the *Mercantile Marine Reporter*, vol. xiv.

"The steamer *Neera* was on a voyage from Liverpool to Alexandria. One night, shortly after passing Gibraltar, at about 10.30 P.M., I went on the bridge, which was then in charge of the third officer, a man of about forty-five years of age, and who up to that time I had supposed to be a trustworthy officer, and competent in every way. I walked up and down the bridge until about 11 P.M., when the third officer and I almost simultaneously saw a light about two points on the starboard bow. I at once saw it was a green light, and knew that no action was called for. To my surprise, the third officer called out to the man at the wheel, 'port,' which he was about to do, when I countermanded the order, and told him to steady his helm, which he did,

and we passed the other steamer safely about half a mile apart. I at once asked the third officer why he had ported his helm to a green light on the starboard bow, but he insisted it was a red light which he had first seen. I tried him repeatedly after this, and although he sometimes gave a correct description of the color of the light, he was as often incorrect, and it was evidently all guesswork. On my return, I applied to have him removed from the ship, as he was, in my opinion, quite unfit to have charge of the deck at night and this application was granted. After this occurrence I always, when taking a strange officer to sea, remained on the bridge with him at night until I had tested his ability to distinguish colors. I cannot imagine anything more dangerous or more likely to lead to fatal accidents than a color-blind man on a steamer's bridge."

A similar experience is thus related by Capt. Heasley, of Liverpool: "After passing through the Straits of Gibraltar, the second officer, who had charge of the deck, gave the order to 'port,' much to my astonishment, for the lights to be seen about a point on the starboard bow were a masthead and green light, but he maintained that it was a masthead and red, and not until both ships were nearly abreast would he acknowledge his mistake. I may add that during the rest of the voyage I never saw him making the same mistake. As a practical seaman I consider a great many accidents at sea arise from color-blindness."

Dr. Farquharson has brought this subject before the House of Commons in England and measures are being taken which will insure to the travelling public immunity from accidents at sea. I need not mention that the majority of railways of our country have a system of examinations which prevents a color-blind entering their service.

Dr. Wilson makes the suggestion that he noticed a singular expression in the eyes of certain of the color-blind difficult to describe. "In some it amounted to a startled expression, as if they were alarmed; in others, to an eager, aimless glance, as if seeking to perceive something but unable to find it; and in certain others to an almost vacant stare, as if their eyes were fixed upon objects beyond the limit of

vision. The expression referred to, which is not at all times equally pronounced, never altogether leaves the eyes which it seems to characterize."

Dr. B. Joy Jeffries, of Boston, has recently written an article on this same topic, but unfortunately I have not his pamphlet at hand to quote his views on this subject.

In this lecture I have shown that the normal eye is far-sighted. The mammalia have this kind of an eye; the Indian the same. The white man is fast becoming near-sighted. The civilized Indian is also showing the effects of continuous near work; and now the question arises, What are we to do to prevent further deterioration of vision? The fault lies at our own doors. Let us try to correct these now existing evils, so that future generations will, instead of censuring us, thank us for our wisdom.

To aid in a feeble way for the protection of posterity I have formulated ten rules on the preservation of vision:

(1) Do not allow light to fall upon the face of a sleeping infant.

(2) Do not allow babies to gaze at a bright light.

(3) Do not send children to school before the age of ten.

(4) Do not allow children to keep their eyes too long on a near object, at any one time.

(5) Do not allow them to study much by artificial light.

(6) Do not allow them to use books with small type.

(7) Do not allow them to read in a railway carriage.

(8) Do not allow boys to smoke tobacco, especially cigarettes.

(9) Do not necessarily ascribe headaches to indigestion, the eyes may be the exciting cause.

(10) Do not allow the itinerant spectacle vendor to prescribe glasses.

New CONSTRUCTIONS of the FORCE of INERTIA of CONNECTING RODS and COUPLERS, and CONSTRUCTIONS of the PRESSURES on their PINS.

By J. F. Klein, D.E.
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The constructions and demonstrations are arranged in the following order:

(*a*) Total force accelerating the rod of the ordinary slider crank, when crank has uniform rotation. Two constructions.

(*b*) Total force accelerating the rod of the crossed slider crank, when crank has a variable rotation and centre of gravity of rod is not on centre line of rod. Construction.

(*c*) Resultant of inertia and weight of rod. Construction and demonstration.

(*d*) Pressure on crank-pin and rotative effect when there is no friction at pins. Construction and demonstration.

(*e*) Pressure on crank-pin and rotative effect when there is friction at pins. Construction and demonstration.

(*f*) The accelerations of the pins of the coupler in the quadric chain when one crank has a uniform rotation. Construction.

(*g*) The accelerations of the pins of the coupler in the quadric chain when both cranks have variable rotation. Construction and demonstration.

(*h*) Demonstrations of the constructions given under (*f*) (*b*) and (*a*) and of auxiliary propositions relating to the formation of acceleration images and the determination of the centre of acceleration.

A.

The mechanism OCW is the ordinary slider crank, in which the stroke of the slide W passes through the centre O of the crank OC. The centre of the rod is at A, the centre of gravity at G and $GF = GD$ is the principal polar radius of gyration.

We will first construct the acceleration of the slide *W* by a simple and new method.

Prolong the rod *WC* till it intersects at *B* the perpendicular *OB* to the stroke *OW*. With *C* as a centre and *CB* as a radius describe a circle *Btv*. On the rod *CW* as a diameter describe another circle. Join the intersections of these circles by the chord *tsv* and prolong it, if necessary, till it cuts a line drawn through crank centre *O* and parallel to stroke. In *Figs. 1* and *2* this intersection is at *w*, and *Ow* is the desired acceleration of the slide provided crank length *CO* represents the centripetal acceleration of the uniformly rotating crank-pin.

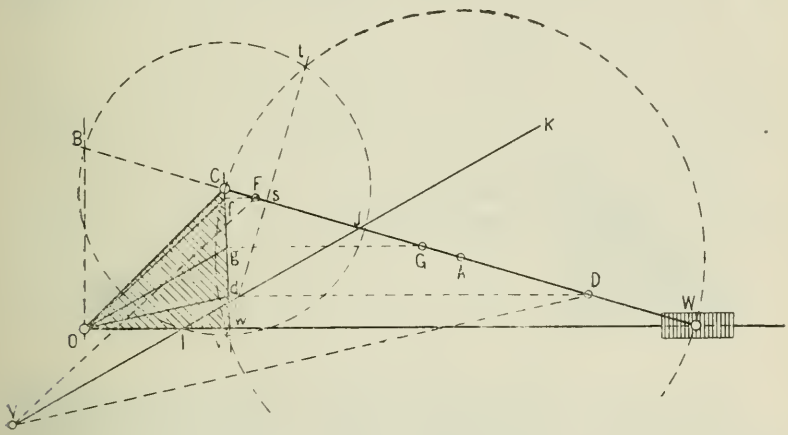

FIG. 1.—First Construction.

(The construction would be exactly the same for the crossed slider crank of *Fig. 3* if its crank had uniform rotation; the acceleration of the slide would then be *Ow*. This construction of the slide acceleration has no failing case even at the dead point.)

Now join *C* and *w*. We will show later that *Cw* is a reduced image of the rod, making with it an angle equal to that made by each point's acceleration with its own radius of acceleration, and we will also show that that point *O* has the same positions relatively to the image *Cw* of the rod that the centre of acceleration has relatively to the rod itself. It follows from this that if we draw through points *F*, *G* and *D* of the rod, parallels *Ff*, *Gg* and *Dd* to the

stroke, that the distances or vectors Of, Og and Od will represent in direction and intensity the accelerations of F, G and D, respectively. The actual location of their accelerations will, of course, be parallels through these points to those vectors. One-half of the mass of the rod is supposed to be concentrated at F and the other half at D.

Draw FV parallel to Of and DV parallel to Od. Through their intersection V draw, parallel to Og, the line VK; it will be the actual location of the resultant force of inertia, and its intensity will equal the product of the whole mass of the rod by acceleration Og of the centre of gravity.

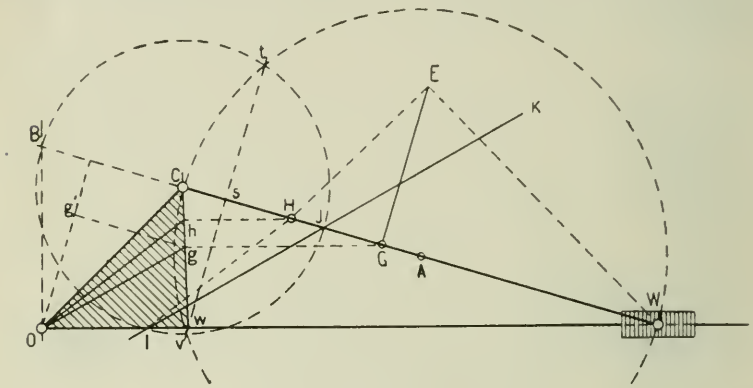

FIG. 2.—Second Construction.

In this case the mass M of the rod is divided into two unequal parts, one of which M_w is concentrated at W and the other M_h at H, the relation between the points W, G and H being $\overline{GW} \times \overline{GH} = k^2$, where k is the principal polar radius of gyration. The two masses must be to each other as

$$M_w : M_h = \overline{GH} : \overline{GW}$$

Construct as before the acceleration Ow of the slide and Cw the image of the rod. At G erect the perpendicular $GE = k$. Join E with W and draw EH at right angles to EW. This will evidently satisfy the condition $\overline{GW} \times \overline{GH} = k^2$.

Through H and G draw Hh and Gg parallel to the stroke, then will the vectors Oh and Og represent in direction and intensity the accelerations of points H and G, respectively.

Through H draw HI parallel to Oh; it will cut at I the direction WI of the acceleration of the other mass at W. Through I draw, parallel to Og, the line IK; it will be the actual location of the resultant force of inertia of the rod, and its intensity = whole mass of rod × acceleration Og of centre of gravity.

These two constructions give, of course, exactly the same result, the first being a little the easiest when the intersection V falls within the limits of the paper. The great advantage of the second is that the direction of W is given by the line of stroke, and that the intersection I will always fall within the limits of the drawing. Both constructions of the total force of inertia fail at the dead point, but this is of no consequence, because then the direction and location of the total acceleration of the rod is known, for it coincides with the stroke, and, as before, its intensity = the whole mass × acceleration Og of the centre of gravity.

This construction is only one of an infinite number of possible cases, each of which satisfies these three conditions:

$$(1)\quad M = M_1 + M_2$$

$$(2)\quad M_1 : M_2 = h_2 : h_1$$

$$(3)\quad h_1\, h_2 = k^2$$

k = principal polar radius of gyration.

h_1 = distance from centre of gravity G of point H_1, at which mass M_1 is concentrated.

h_2 = distance from centre of gravity G of point H_2, at which mass M_2 is concentrated.

M = total mass of rod. The points H_1 and H_2 lie in one straight line with G, and on opposite sides of G. By transformation and combination, we get

$$M_1\, h_1 = M_2\, h_2, \qquad \text{and} \qquad M_1\, h_1^2 + M_2\, h_2^2 = M\, k^2$$

which shows that any concentration of mass satisfying the above three conditions will develop the same pressures on its supports, and store the same energy as the original distributed mass. It is evident that $h_1 = h_2$ is a particular case of the general one just given, and is illustrated in

Fig. 1. Neither of the points H_1, H_2 is necessarily located at wrist-pin centre W, or on centre line CW of rod.

B.

This is meant to be the most general case of slider crank, with respect to the mechanism itself, to its motion and to the distribution of the mass of the rod. The mechanism LCW is of the crossed slider-crank type in which the stroke of slide W does not pass through centre L of crank. The rotation of crank CL is not uniform as in the preceding cases, the acceleration of crank-pin C, taking (say) the direction and intensity CO, instead of CL as before.

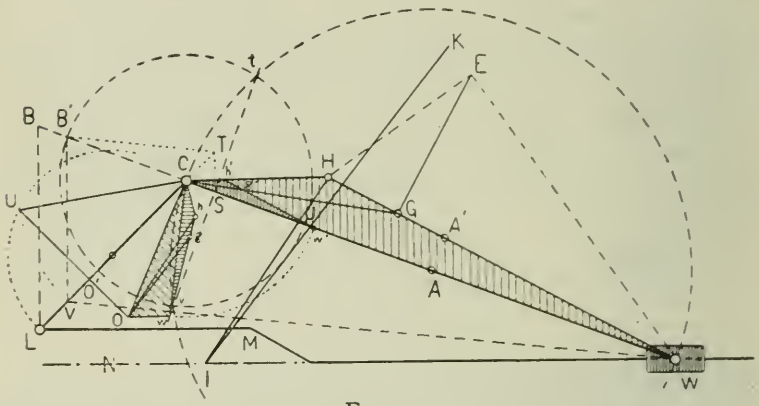

FIG. 3.

The centre of gravity of the mass is no longer in the centre line CW of the rod, but outside of it, at G. The point H is on the line WG as before, and again satisfies the condition $GW \times GH = k^2$, where k is the principal polar radius of gyration. H is found by the same construction, namely, we erect the perpendicular $GE = k$, join EW and draw EH at right angles to EW.

The velocity of the crank-pin is no longer represented by CL, as in *Figs. 1* and *2*, but by CV. It is found by construction, as follows: On crank CL as a diameter construct a circle LUC; from end O of acceleration draw a perpendicular $OO'U$ to CL; then will $CU = CV$ be the intensity of the velocity of the crank-pin C. To find the acceleration Ow of

slide, we proceed as in *Figs. 1* and *2*, except that a circle is described with CB' as a radius instead of CB.

In *Fig. 3* the distance OC and Ow, respectively, represent the accelerations of crank-pin C and wrist-pin W. The line Cw is the reduced image of the centre line CW of the rod. We may consider this rod to be an exaggerated specimen of the Westinghouse type in that its centre of gravity G is off the centre line CW of the rod. We may regard the triangle $CHGW$ as the representation of the rod and proceed to construct a reduced image of it on Cw as a base. To do this lay off $Cw' = Cw$, draw $w'h'$ parallel to WH and connect C with G. The triangle $Ch'g'w'$ is evidently similar to $CHGW$. Revolving it back to Cw as a base we get triangle $Chgw$ as the desired image of the rod, and Oh, Og will be, in direction and intensity, the accelerations of points H, G, respectively. Through H draw HI parallel to Oh; it will cut at I the direction WI of the acceleration of the other mass at W. Through I draw, parallel to Og, the line IK; it will be the actual location of the resultant force of inertia of the rod, and its intensity, as before, is equal to the product of the whole mass of rod $\times$ acceleration Og of the centre of gravity.

C.

An exact determination of the pressure exerted by rod against the crank- and wrist-pins must include its weight.

We will, therefore, find the resultant of the weight and of the resistance due to inertia. As the inertia is measured by mass times acceleration, the expression of the force of inertia becomes:

$$\text{Inertia of rod} = \frac{W}{g} \times \frac{\overline{Og}}{\overline{OC}} \times \frac{v^2}{R} = F_2$$

W = weight of rod in pounds;
v = velocity of crank-pin in feet per second;
R = radius of crank in feet; and
g = acceleration due to gravity = 32·16 feet.

$\overline{Og}$ and $\overline{OC}$ = accelerations of centre of gravity and of crank-pin as given by *Figs. 1* and *2*. In the case of *Fig. 3*, we must substitute in the above expression for $\overline{OC}$ the value

$\overline{O'C}$. As the forces connected with engine are usually reduced to pressure per square inch of piston, the total inertia above given and the weight W should be divided by the area A.

In *Fig. 4* pass a vertical GQ through the centre of gravity G till it cuts the direction IK of the force of inertia of the rod. Make QS = weight of rod per square inch of piston, and QK = inertia of rod per square inch of piston. Complete the parallelogram; we get the diagonal PQR as the desired resultant of weight and inertia. This resultant must be overcome by the combined action of the pressures of crank- and wrist-pin.

Example: Harris-Corliss engine, $26\frac{1}{8} \times 60$ r.p.m. = 60. Length of rod = 150 inches. Weight of rod = 1,200

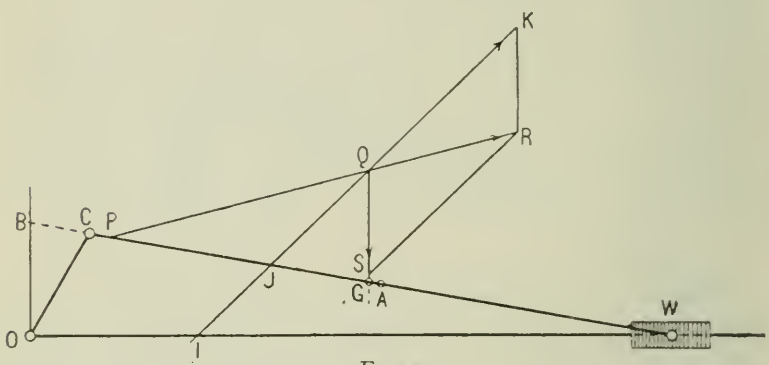

FIG. 4

pounds. Weight of other reciprocating parts = 1,300 pounds. Radius of crank = 2·5 feet. v = 15·71 feet per second. v^2 = 246·74. Principal polar radius of gyration = k = 48 inches. Distance of centre of gravity from wrist-pin = 78 inches. Distance of centre of oscillation from centre of gravity = 29·57. Assuming crank at 60° and drawing the mechanism to a scale of an inch to the foot, we get $\overline{Og}$ = 1·595 inches and $\overline{OC}$ = 2·5 inches. Substituting in the above formula and dividing by A, we have

$$\frac{F_2}{A} = 4{\cdot}38 = \overline{QK} \qquad \text{and} \qquad \frac{W}{A} = 2{\cdot}24 = \overline{QS}.$$

Exact computation * gives

$$\frac{F_2}{A} = 4{\cdot}37$$

which differs but 0·01 pounds per square inch from the result obtained by the graphical method. Considering the small scale, one-twelfth, employed, this shows the practical excellence of the graphical method.

In the above example the weight is about one-half of the inertia, but that is because the engine was large and of comparatively slow speed. In small, high-speed engines, the proportion is much less. Thus, in a *N. Y. S. S. P.* engine, 10 x 12, with rod of seventy pounds and 300 r.p.m. (*i. e.*, same crank-pin speed as in the large engine) we found

$$\frac{W}{A} = 0{\cdot}89 \qquad \text{and} \qquad \frac{F_2}{A} = 9{\cdot}21$$

or weight = one-tenth inertia. In the latter case the resultant will differ but little from the inertia in direction and intensity.

D.

When there is no friction at the pins, let P_c and P_w represent respectively the crank-pin and wrist-pin pressure. Let line *lq*, *Fig. 5*, represent the direction of the resultant of the weight and inertia of rod, and let the intensity of this resultant be assumed equal to $F_3 = lp = kh$. It is evident P_c and P_w combined must equal this resultant, and if one of these forces (say P_w) is known, the other P_c can be found by the parallelogram of forces. To obtain P_w we must satisfy two conditions, one of which is that P_w must do its part in producing the resultant F_3, acting along *lq*, and the other that P_w must balance the resultant of the guide reaction G and the driving force K of the piston. This force K is the

* The computation was made by the help of formulæ developed by Profs. Jacobus and Webb, in a paper published in *Trans. Am. Soc. Mech'l Eng.*, vol. xi. The data for the above example were obtained from this same source (see p. 498). The paper is analytical in character, but lays due stress on the practical questions involved; it is a valuable contribution to the subject of transmission of force in steam engines.

difference between the effective steam pressure P and the inertia F of piston, piston-rod and cross-head.

Through W draw Wz equal and parallel to F_3 ($= lp = kh$). Join any point l on lq with C and W. Draw zv and Wv, respectively, parallel to lC and lW. Through the intersection v draw vS parallel to centre line CW of rod, which line also represents direction of internal stress as C and W are the points of application of the forces. We will show later, that this parallel tS is the locus of the ends of all forces applied at W that satisfy the first condition mentioned above. Now lay off $Wb = K = P - F_1 =$ driving force and draw bt parallel to guide reaction G. The line bt is the locus of the ends

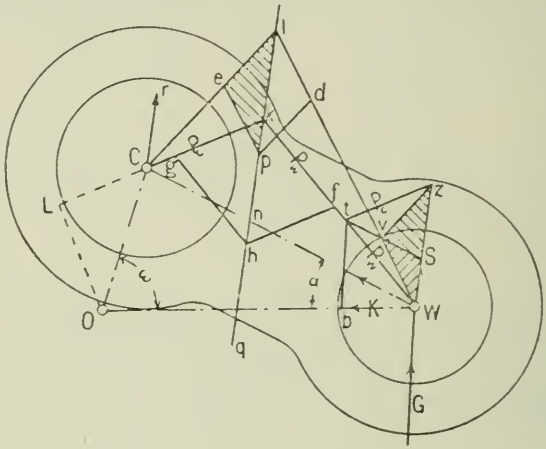

FIG. 5.

of all forces applied at W that satisfy the second condition. The intersection t of these two loci St and bt, gives $Wt = P_w$ the force desired. Prolong Wt to point k on line of resultant, then making $kh = F_3$ and $kf = Wt = P_w$ and completing the parallelogram, we get the crank-pin pressure $P_c = kg$ and the rotative effect $= P_c \times OL$.

For convenience of expression we will speak of the two components of each pin pressure as internal-stress-component and inertia-component. *The latter expression is not strictly correct as the second component not only overcomes the inertia but also sustains the weight of the rod,* but this will not at all affect the accuracy of our results.

Since the force P_c passes through crank-pin centre C, and may have its point of application anywhere on its line of direction without affecting its accelerating capacity, we will assume this point to be at C, and since force P_w passes through wrist-pin centre W, we will, for the same reason, take its point of application at W. This will make the centre line CW of the rod the direction of the internal stress caused by either P_c or P_w. Although the intensity of this internal stress varies as the inertia components of P_c and P_w are varied, nevertheless there is but one pair of forces P_c, P_w that will satisfy the conditions of this problem. To prove this it is only necessary to show that there is only one force P_w that will satisfy the conditions at the wrist-pin. One condition is that it shall be in equilibrium with the known force $K = P - F = Wb$ and the partly known reaction G of the guides. By drawing through b a parallel bt to the known direction of G, we get one locus for the end of the force P_w. Another condition that P_w must satisfy is, that it shall be the resultant of the internal stress acting along CW and the corresponding inertia component acting in any arbitrarily chosen direction. Let Wl be any such direction, then Cl will be the direction of the corresponding inertia component that acts at the crank-pin C. If $kh = lp = Wz = F_3$ is the known resultant of the weight and inertia of the rod, then $ld = Wv$ is the intensity of the inertia component acting along the assumed direction Wl, and $le = vz$ is the inertia component along Cl. Now draw through v a parallel Svt to the inner stress CW; it will divide the triangle Wvz into two triangles WSv and zvS, respectively, similar to triangles Wnl and lnC. Hence,

$$\overline{nW} \times \overline{SW} = \overline{vS} \times \overline{ln} = \overline{nC} \times \overline{Sz}$$

and

$$\frac{WS}{Sz} = \frac{nC}{n\,W} = \text{constant}$$

for this position and motion of the rod. Since Wz is also constant for this position of rod, the parallel Svt will pass through the same point S whatever the direction and intensity Wv of the inertia component. Therefore, the

intersection of Svt with the locus bt will give Wt as the only possible value of P_w for this position and motion of the rod.

Prolonging P_w to k and drawing kC and also tz, we get $P_c = kg = tz$. It is also evident from the figure that the reaction $G = bt$ of the guide is independent of the direction and intensity of the inertia component.

E.

When there is friction at the pins, let P_{cf} and P_{wf} represent, respectively, the crank-pin and wrist-pin pressures, and let GKL, *Fig. 6*, represent as before the location of the resultant F_3 of weight and inertia of rod. We will again suppose $F_3 = GN = KQ = PO = TL$ to be known. In this, as in the former case, P_{cf} and P_{wf} combined must be able to sustain the weight and overcome the inertia of the rod.

Moreover, P_{cf} must be tangent to a circle described from C as a centre with $\varphi\, r_c$ as a radius, and P_{wf} must be tangent to a similar circle about W with $\varphi\, r_w$ as a radius where φ is coëfficient of journal friction, and r_c, r_w, the radii, respectively, of crank-pin and wrist-pin. These circles are called friction circles, and have been in use for some time by writers on engineering. *No demonstrations concerning them need, therefore, be given here; we will simply say that each force is drawn on that side of the friction circle which will give a component opposed to the motion of the eye or pin according as the action of the pin or action of the eye is the force under consideration.

In *Fig. 6* the friction circles have been greatly exaggerated, and the rod given unusual proportions for the purpose of better illustration.

With this modification the force P_{wf} must satisfy the same two conditions as in the preceding case. But in that case it was known that P_w passed through the centre W of wrist-pin, and that point could, therefore, be assumed as its point of application. In the present case the possible values

*See Rankine's *Machinery and Millwork*, p. 428. Also Hermann-Smith's *Graphical Statics of Mechanism*, pp. 39–76.

of P_{wf} do not pass through such a common point, and we must, therefore, make use of trial methods to find P_{wf}.

We will first give a method which is, theoretically, the most exact, and then another, which is simpler, and, at the same time, accurate beyond the needs of practice.

From each of the series of points G, P, T on the line GL draw a tangent to each of the two friction circles *mnq* and *klp*. Make distances $GN = PQ = TL$ equal to the known force F_3 and resolve each of these distances into components

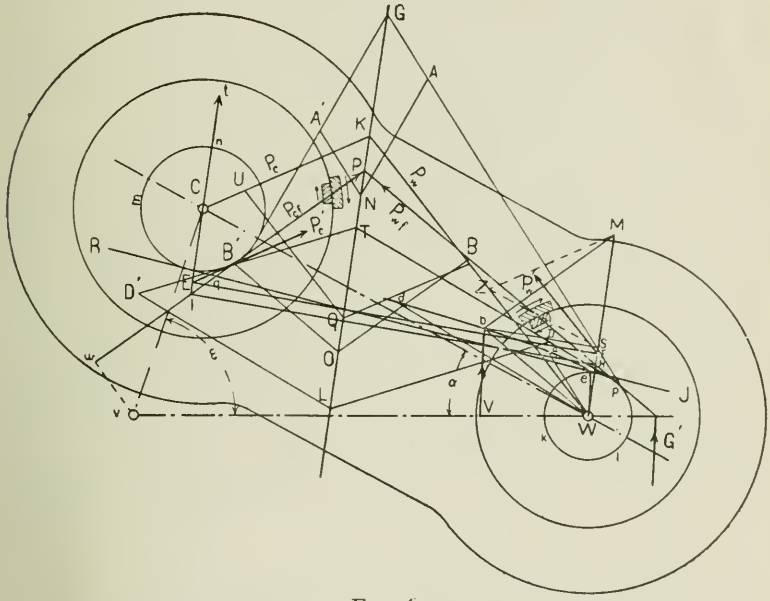

FIG. 6.

along the respective tangents. Then with W as a pole draw Wa equal and parallel to GA, Wb equal and parallel to PB, also Wd equal and parallel to TD, and so on, thus getting a polar curve *eabd*, whose vectors satisfy the condition that the pin forces shall be capable of balancing the resultant F_3. The second condition is the same in this as in the preceding case, namely, that the wrist-pin pressure P_{wf} shall be in equilibrium with the driving force $K = WV = P - F_1$, and the given reaction G (known in direction only). Now, laying off $\overline{WV} = K$, drawing Vb parallel to the guide reac-

tion G', and joining its intersection b (with the polar curve $eabd$), to the pole W, we get in Wb the exact intensity and direction of the wrist-pin pressure P_{wf}, but not its location. The latter is found by drawing HBP parallel to Wb and tangent to the friction circle plk. Finally, drawing $PB'I$ tangent to friction circle mnq of pin C, and constructing the parallelogram of forces, we have $PB = Wb = P_{wf}$ and $PB' = P_{cf}$, the exact pin forces desired. The rotative force is measured by $P_{cf} \times \overline{\tau w}$.

In the simpler and only theoretically less exact method, the principal steps are like those taken in finding P_c and P_w, in *Fig. 5*. The direction of the internal stress is, however, no longer CW, and a determination of a convenient direction for it, constitutes the main portion of the problem.

To illustrate the method, suppose the problem solved and the forces P_{cf} and P_{wf} just found to be each resolved into two components, one parallel to GL and passing through C and W, respectively, and the other in the direction of the internal stress. The two components parallel to GL must together just equal F_3 and, therefore, be capable of sustaining the weight and overcoming the inertia of the rod. The direction of each of the two internal stress components will evidently be HI, and according to d'Alembert's principle they will just balance each other. Inspection of the figure will show that for friction-circle-tangents differing but slightly in direction from P_{cf} and P_{wf}, the direction of the internal stress will also differ but slightly from HI. This is the case even in the present figure, where the rod is very short and the friction circles excessively large. Now, P_w differs but little, in direction from P_{wf}, and if we draw P_w' parallel to P_w and tangent to the friction circle plk, the location of this tangent will differ but little from the actual force P_{wf}. For the same reason P_c', parallel to P_c and tangent to qmn, will differ but little from P_{cf}. Joining the intersections F and E (of P_w' and P_c' with the parallel components WM and Ct, respectively), we get in FE a line whose direction is nearly parallel to the exact direction of the internal stress HI.

Our procedure in finding P_{wf} is, therefore, as follows: We

get the component WS as it was got in *Fig.* 5; we next draw through S a parallel Sb to the line FE, just described; then will Sb be a locus of the end b of the desired force Wb. But another locus is needed to completely determine b; this is given by the condition that $Wb = P_{wf}$ shall be the resultant of the driving force $K = P - F_1$, and guide reaction G'. Therefore, laying off $WV = K$ and drawing Vb parallel to G' we get a second locus whose intersection b with the first locus Sb gives the desired intensity Wb of the force P_{wf}, for Wb is common to each of the force triangles WSb and WVb, thus satisfying both conditions imposed upon P_{wf}. The exact location of P_{wf} may now be found by drawing pBP parallel to Wb and tangent to the friction circle plk. The accuracy of the work may be checked by completing the parallelogram $OBPB'$ and seeing if $PB = Wb$.

The approximation just given can be still further simplified for all cases that may arise in practice. In such cases the friction circles are very small and far apart, and the tangent RJ to both friction circles is scarcely distinguishable from the direction HI or EF. We may therefore treat this tangent RJ as the direction of the internal stress, draw Sb parallel and then proceed as above in the determination of Wb and location of its equal P_{wf}. The inaccuracy involved in this last approximate construction is much less than that connected with the best determined coëfficients of friction.

F.

The quadric chain $ABCD$ is one of interest because its derivatives are so extensively used in practice. We will now consider the special case in which one of the cranks (or levers), say AB, *Fig.* 7, has a uniform angular velocity. The velocity v, and acceleration $\frac{v^2}{R}$ of pin A may then each be represented by the length $AB = R$ of the crank. The direction AB of the acceleration of A, of course, coincides with the crank. If we suppose the direction of the velocity v of the pin A to be revolved through 90°, then in a certain sense the crank AB may be said to represent A's

velocity and its direction. The following beautiful and symmetrical construction of the acceleration of pin D, for this special case, was first given by Prof. T. Rittershaus, in *Der Civil Ingenieur*, 1880, p. 244, and in *Zeitschrift des Vereines deutscher Ingenieure*, pp. 287–289, 1883.

Prolong the opposite sides AB, CD and AD, BC to their intersections, the instantaneous centres P and Q. Through crank centre B draw BJ parallel to CD and BI parallel to AD. Join J with P and I with Q. Where JP cuts the par allel BI erect a perpendicular OS to BI, and where IQ cuts the parallel BJ erect the perpendicular NS to BJ. Then will JS represent in direction and intensity the acceleration of pin D, the common point of lever CD and of link or coupler

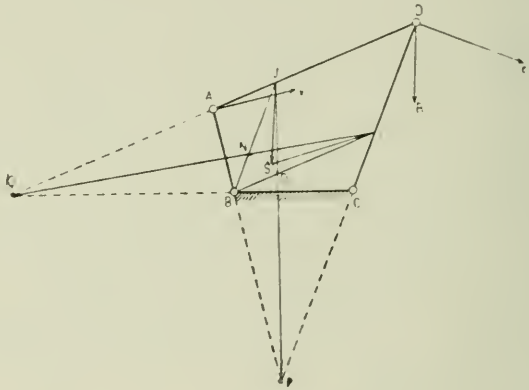

FIG. 7.

AD. Transferring JS to point D we have in DR the completely determined acceleration of point D.

If AB were the stationary link of the mechanism and BC the crank moving with constant angular velocity, IS would represent in direction and intensity the acceleration of point D.

[*To be continued.*]

CONFLAGRATIONS IN CITIES.

By C. J. H. Woodbury,
Vice-President Boston Manufacturers' Mutual Fire Insurance Company, Boston, Mass.

[*A lecture delivered before the Franklin Institute, Philadelphia, Jan. 23, 1891.*]

[*Concluded from p. 141.*]

There is scarcely a fire department which could not be feasibly reorganized by assigning one set of men to the care of apparatus, and another portion of the men—whose duty as hosemen and the like is to enter buildings at time of fire—to the inspection of buildings.

A measure of the benefit that might be derived from such work is shown in the reports of the underwriters' inspections in cities where such inspection service has been organized. The Inspection Department of the Boston Board of Fire Underwriters, organized June, 1884, and making about 11,000 inspections a year, has given very satisfactory results, indeed, particularly in regard to the improvement of property occupied by tenants, where the owners of buildings have been very much surprised at receiving information concerning dangerous conditions of which they had no knowledge, and have at once proceeded to correct the defects—the number of recorded improvements being 6,409 during the past year.

The results of the inspection at Boston have caused the organization of similar inspections in other cities, particularly at the West, where the work has been entered upon with much enterprise.

In Chicago the Inspection Department of the Fire Underwriters' Association makes about 16,500 inspections a year, disclosing 13,500 defects; and ninety-seven per cent. of these defects are reported as remedied. This department was organized in February, 1886, and great as has been the number of defects reported, the large proportion of corrections shows that the inspectors have not made requirements that were in the least degree impracticable.

In Philadelphia, the admirably organized Fire Underwriters' Association, which is broader in its scope than similar combinations in other cities, has had a corresponding increase in success, directly traceable to the efforts of its representatives.

The oldest inspection service, certainly in this country, is that at Moravian town of Salem, N. C., where a municipal fire inspection has been carried on for about 100 years, during which time there has not been an instance of a fire loss exceeding $1,000. Of course, the conditions there render large losses out of the question; but the adjoining new town of Winston, which has refused to adopt that method of inspection, has been subjected to numerous fire losses, although the physical conditions of the two communities cannot be far different from each other. My informant ascribes this difference in the fire loss to the municipal inspection at Salem.

The protective organizations, maintained in most large cities by the underwriters, have performed a vast deal of good work in the saving of property, but as stated in referring to the inspection corps, why should not such an organization, which is for the benefit of all, be directly sustained by the community as a public expense?

The methods of Factory Mutual Companies are often cited as proof of what can be done in reducing the fire loss; but the comparison is not exact in its application to methods which are feasible under conditions exposed to the conflagration hazard.

While it is absolutely true that these companies, or rather co-operations, have, for a series of over forty years, insured on a sound financial basis isolated industrial property devoted to the normally hazardous process of textile manufacture, paper making, and many varieties of metal working, at an annual cost in the vicinity of one-fifth of one per cent., or twenty cents on the $100—with the expectancy of a still lower cost in the immediate future, judging by the experience of recent years—yet it is questionable whether similar methods reaching identical results, are in any measure feasible for commercial risks in cities. It must be remem-

bered that these results are obtained from the peculiar conditions of a class of insurance.

The autonomy of these Mutual risks is well defined. Their isolation not only includes the absence of the conflagration hazard, but also a remoteness, or even entire absence of the services of an efficient public fire department, and therefore the policing of such property is most thorough.

The rules governing the operatives in the care of waste and dirt, the espionage of the watchman, whose patrol is recorded on a watchman's clock, the close supervision of the manager and his assistants, and in the generality of instances the methods of slow burning construction, isolating each room from the others without regard to architectural effects, the removal of unduly dangerous processes, as picking and dusting, from main buildings, the concentration of fire apparatus, pails kept filled with water, automatic sprinklers ready for instantaneous service, and numerous hydrants and hose at every point of advantage, furnished with powerful pumps and two independent sources of water supply, the apparatus manned by those who know every inch of the property protected; are all conditions which are entirely consistent with an insurance cost of one-fifth of one per cent.; and the wonder is that these precautions do not make the rate still less.

Such methods cannot be applied, except in part and in lesser degree, to commercial city risks; but every bit of experience goes to prove that they are of value in city risks to the measure that they are applied.

The great need is that of an awakened public sentiment, not merely in regard to a general knowledge of the causes of fire and the simple methods of their prevention, but also in regard to a general understanding of the fact that the cost of insurance is diminished with the adoption of every measure which tends to reduce the fire hazard.

FIRE-RESISTING CONSTRUCTION.

While the origin of most fires is due to causes which are in the control of owners or occupants, the destructive extent of nearly half of the fires is due to faulty methods of con-

struction, which might have been prevented in greater or less degree by the adoption of methods not involving excessive expense or unusual appearances in construction. These methods of safer construction are matters of common knowledge among competent architects, but they should not be held at fault for mistakes due to the avarice or prejudice of owners.

Methods of building construction, with a view to the application of methods of the greatest safety, need not interfere with the free exercise of the highest degree of taste. An ugly building is not necessarily a substantial one, any more than a homely person is necessarily good—although the greater portion of humanity willingly find comfort in the proverb concerning the Flemish beauty and the accompanying intrinsic merit.

The work of the underwriter is largely dependent on that of the architect, because every variety of building material and every method of construction, irrespective of the use to which the building is put, is more or less destructible by fire; therefore, the work of the architect must be judged, in a certain measure, by the methods of the underwriter.

There are certain types of construction of commercial and manufacturing buildings in cities, which experience has shown to be peculiarly adapted to resist destruction by fire, and a general consideration will be given to some of these methods.

If a building could be so constructed that its contents could burn and destroy the interior, without endangering the neighboring buildings, it could never cause a conflagration. A fire-proof building, however, is a commercial impossibility, because if one could be constructed so as to withstand the destruction of its contents, it would be good for little else, and the cost would be prohibitive.

When William A. Green was Chief of the Boston Fire Department, he received a letter from an official at Berlin, asking for a description of the fire-proof public buildings at Boston. He replied that they had but one, the Beacon Hill Reservoir, and sometimes they did not feel quite sure of that.

Improvements on the score of safety to buildings in cities are feasible only so far as they do not offend the present methods of taste in design, or interfere with the purposes for which such buildings are to be used; and all modifications must be made without undue cost, and under such conditions that any additional expense will prove a good investment in the diminution of the fire hazard, as measured by a reduction in the rates of insurance.

Any other method of treating the question in the attempt to direct the construction of buildings, regardless of all considerations except the reduction of the fire hazard, would be comparable to the answer of Brunel, the Civil Engineer, when he told the Parliamentary Commission that he believed the purpose of the Creator in making rivers was to feed canals.

The methods of safe and solid construction are, however, less expensive than the hollowness of alleged decorations, whose only definite characteristic consists in their perfect fitness as fire traps.

These questions of safe construction naturally resolve into two classes, the one including measures to prevent fires communicating from one building to another, and the other including measures to obstruct a fire from extending throughout the various stories of a building.

Both of these conditions may be idealities as to their complete fulfilment, but it has been found feasible to reach favorable results in these directions.

Any building ordinances which pertain solely to the entire construction of new buildings will be very slow in their application; but in most instances, changes can readily be introduced which would materially diminish both classes of hazard. Any measures which could do away with the conflagration hazard in cities would reduce the fire loss very materially.

The first consideration should be given to the means of reducing the conflagration hazard. This is accomplished simply by the maintenance of the walls, the protection of all necessary openings, the abolition of wood cornices, and the protection of the roof, all of which precautions have been taken in most of the first-class buildings in cities.

Brick division walls, heavy enough to withstand the excessive stresses incident to a fire, will be uninjured by flames which cripple iron and decrepitate stone. It is preferable that all walls should extend above the roofs; but where that cannot be done the cornices should be of terra-cotta, stone, or metal.

All openings in side or rear walls which would become a source of danger in case the adjacent buildings were on fire, should be provided with fire-proof doors or shutters, which should always be closed at night.

These doors or shutters should be made of two thicknesses of matched boards, of thoroughly seasoned stock, laid at right angles to each other and covered with sheets of tinned iron laid with locked joints similar to the method generally used in tin roofing. The hangings, whether trucks or hinges, should be secured directly to the wall, and fastened to the door or shutter by carriage bolts, not screws.

The butts for outside shutters should be made of galvanized iron, or some other material which would not allow the hinge to stick by rust. In division walls of large buildings these doors should be double, one door at each side of the wall.

Doors made after such a method have resisted the most severe exposure in burning buildings; while it is known that either wrought or cast-iron doors cannot withstand the heat of any considerable fire.

The occupant of a large building in Boston asked advice upon the best methods to render the building safer, and among other matters, it was suggested that tinned fire-doors should be placed at the openings in the division walls in place of the iron doors.

He replied that he would most gladly make the change, were it not that the conditions of the lease made it necessary that iron doors shall be kept at these openings. But, on being asked if any clause of the lease forbade the addition of tinned fire-doors in front of the iron doors, he replied in the negative, and afterwards had some excellent fire-doors made. They were, however, hung on hinges secured to the *furring* and *not* to the brick wall.

In a short time a fire started in the building, and, passing up the hollow spaces between the studding and the wall, caused the whole finish to separate from the wall, carrying the fire-door to the cellar, where it lay among some burning anthracite coal for a week, and was then removed to a certain insurance office, where it served as an excellent example for many years.

The iron fire-proof door, did not long remain in position after the tinned door was pulled away from in front of it, but yielded and allowed the fire to proceed through the opening into the adjoining building.

The floor supports should be attached to the walls in such a way that the walls shall not be injured by falling beams or girders. The preferable means for accomplishing this result is first to place the beams so they will not penetrate too near to the outer face of the wall. They should then be secured to the walls by a wall-plate with a tongue entering a transverse groove across the under side of the beam, or by the cast-iron anchorage box invented by Henry A. Goetz, the well-known architect. Wood beams anchored to the walls by either of these two methods will not endanger the walls in the event of a beam falling from any cause.

In the case of iron girders the problem is different, as the changes in the length of such girders with ordinary variations in temperature would not permit a rigid anchorage. This expansion has been sufficient in case of fire to produce serious results.

In his report on the great fire of November 28, 1889, the Boston Fire Marshal states, in regard to the Ames Building, which was among those destroyed, that the walls of the building were thrown out by the expansion of the iron roof. (*Boston City Document*, No. 17, 1890, p. 8.) Allegations have also been made concerning destructive results caused by the expansion of iron girders at other fires.

The question of roofs is a very important one, both in regard to their yielding from a fire inside, and also their ignition from outside exposure. The statement made by Benjamin Franklin, that "next to a good foundation, a good roof is the most important part of a house," is even more

applicable to-day, as the crowded condition of cities has given other functions to roofs than merely those of shelter.

The most substantial roofs for commercial buildings are those constructed of plank, and nearly flat, having a slope of half an inch to the foot either towards the centre or the edges. When the various courses of roof-covering comprise a solid thickness of three inches of wood without any intervening air-space, then the building is covered with a roof which will protect the upper story against extremes of temperature, resisting both the heat of summer and the cold of winter. A fire of the contents would not burn through such a roof so long as the supports were intact; and if the outside was protected by any roof-coverings suitable for flat roofs, it would be difficult for a neighboring fire to inflict any injury on such a roof. It is important that such a roof should have an opening covered with a door as thick as the roof, and that it should be provided with a permanent ladder or stairway leading to it.

The questions relative to the protection of buildings against fires originating in them, involve matters of detail pertaining to methods of interior construction and occupation which in themselves would exceed the limits of my allotted time; but at the risk of making some digressions not strictly bearing upon conflagrations, except in that relation which one fire always bears to another, the importance of the subject is offered as an excuse for referring to some of the salient features of interior defence against fire.

President F. C. Moore, of the Continental Insurance Company, states in his monograph on *Economical Fire Resisting Construction*, p. 4, that of the fires which exceed $100 in damage, only one-fifth are extinguished short of total destruction of the building and its contents.

In connection with this, it may be interesting to note the percentage of fires which caused a partial loss amounting to over $100 as compared with those which resulted in the general destruction of the building and contents, as shown in the reports of fires on property insured by the Boston Manufacturers' Mutual Fire Insurance Company, from which it is learned that in the last thirteen years there have been

457 fires, causing a damage of $100 or over, and only sixty-one of these fires may be classed as total losses, having caused the general destruction of the building and contents.

The greater proportion of the fires noted as total losses were in mill tenements, store-houses and dye-houses—classes of property whose conditions do not permit the application of methods of protection in general use in mills.

These facts in regard to fires occurring upon manufacturing property of normally great hazard, serve to show what results have been obtained by suitable precautions in the way of construction, fire apparatus and care.

It is not easy to introduce changes in the hazard of dwellings, as their owners and occupants are not inclined to vary from customary methods, but the owners of mercantile and manufacturing property are far more ready to give consideration to suggestions designed to reduce the fire risk.

A building made of incombustible material is not necessarily fire-resisting, as a combustion of the contents of almost all commercial buildings, except office buildings, will weaken unprotected iron beams and columns, and reduce the strongest stone to powder. This destruction of rock is caused by the conversion into steam of the water absorbed by the stone.

Nearly every city is provided with building regulations, which are generally teeming with errors of omission, and often contain provisions for methods of construction which are as far behind the times as the old buildings which are torn down to make way for the new structures to be erected in accordance with the provisions of the new regulations.

The increasing height of buildings, whose profitable use has been made possible by the passenger elevator—which was very properly designated by its inventor, Otis Tufts, in his patent as the vertical railway—presents a problem which is not fully met by the use of incombustible material in construction.

This increase in the height of buildings was clearly indicated a short time ago by one of the magazines (*Harper's*

Magazine, November, 1882), which contained two views of the Southern part of New York City—the one being from a daguerrotype of many years ago, and the other from a recent photograph taken from the same place in Brooklyn. Trinity steeple and a few landmarks served as scales by which to estimate the increasing height of buildings, which appeared to average certainly more than double—with exceptional examples lofty enough to suggest the sin of Babel.

Want of care in the construction of flues or chimneys is the cause of an enormous number of fires, especially from cracks caused in many instances by girders or beams too near chimneys. Soot deposited in such cracks becomes ignited in the course of time, and acts as a fuse to ignite some of the wood-work at the floors, or the interior finish of the building.

Hollow concealed spaces in floors and walls are a source of great destruction by fire. It is certainly preferable, as regards matters of safety, to design buildings without such dangerous spaces; but the traditions of construction seem to be so entirely opposed to such methods that they must be recognized, and faulty practice modified as far as possible by the introduction of fire stops in all vertical concealed spaces at each story, and any continuous spaces, particularly in the attic, should be cut off at as frequent intervals as can be arranged.

The ceilings over furnaces, boilers, and hotel cooking apparatus, if near enough to become in any manner a source of danger, require special provisions to insure safety. All hollow spaces should be removed, and wood-work is generally best protected by means of lime plaster laid on wire lathing, conforming to the surface of the under side of the floor.

The supports of a building should be arranged to resist injury as a result of the combustion of the contents, or of the lighter portion of the interior. Timber beams and columns fulfil this purpose as well as any material; but it is frequently necessary to use iron or steel to obtain the necessary strength, in which case the metal should be protected

with heat-resisting material, generally with special tiles made for the purpose.

The best type of a commercial building is that in which the floors are continuous; the openings for elevators, stairs, and transmission of power, being an enclosed tower. This isolation of the various rooms from each other would render such a building well nigh indestructible by fire, but such a separation would not generally be considered adapted to commercial buildings, with the exception of store-houses. During the last year I designed a six-story building of this description, which is situated in the compact portion of a city, and occupied by numerous tenants engaged in various kinds of manufacturing.

The floors of this building are of the usual slow-burning construction type, the timbers consisting of southern pine beams of eighteen feet span, bolted in pairs, making solid beams 12 x 14 inches, and laid eight feet on centres.

The floors upon these beams consist of three-inch spruce plank planed underneath and with splined edges. These planks are sixteen feet in length, and therefore, each one rests on three beams. In order to render the load on the beams uniform, the courses are broken every two feet. Two thicknesses of asbestos paper are laid on the plank before the top flooring of birch is laid.

The roof is similar in construction, but only three inches thick. It is lowest in the middle, and the brick walls form a parapet around the sides. All windows, except those at the front, are provided with tinned shutters.

The peculiar feature of the building, however, is the means used to isolate the various stories from each other by making the floors entirely continuous and without any openings whatsoever.

A tower in the middle of the building, placed 24 feet from the entrance, and measuring 10 x 17 feet, made of brick in the lower portion and 3-inch plank above, extends through the roof and is covered by a large skylight protected, as all skylights should be, by wire netting underneath.

This tower contains stairways and elevator; and at the rear is another division for the wash-rooms, and to carry

steam- and water-pipes. Adjoining this is the belt tower, the power being transmitted to each room along a line of shafting. The whole arrangement occupies an area 10 x 31 feet in the middle of the building, where the light is the poorest, being therefore the space least valuable.

This method of interior construction, instead of being an added expense, cost about $3,500 less than the estimates for a similar structure with joisted floors of equal strength and rooms of the same height in the clear.

The rate of insurance is said to be the lowest ever given to a building under those conditions of occupancy, height and exposure to conflagration hazard.

Similar methods can be applied to other commercial buildings, but it is doubtful whether this method of arranging a stairway might not interfere with the requirements necessary in many commercial buildings, particularly those devoted to retail business, and buildings where elaborate decoration in interior finish is desired; although in buildings where such displays are necessary, the construction could be rendered more fire-resisting by the adoption of methods involving a higher expense than the ordinary methods.

The advantage of sound construction has never been more strongly illustrated than in Paris during the commune of 1871, when the mob sought to burn the city by the free use of kerosene, and only succeeded in burning the individual buildings which were set on fire, notwithstanding that there was no fire department to combat the fires. Photographs of streets taken after these fires show that the front walls of the burned buildings were still intact.

Fire Apparatus.—Experience has shown that the most effective measures against the fire hazard are those in the nature of precautions. The inception of fires should be guarded against by taking especial care of all matters tending to originate or spread fires; and, secondly, methods of construction which tend to prevent the spread of fire from one building to another, and also to retard the progress of a fire through the same building, should be used.

Before referring to any forms of fire apparatus, consideration should be given to the service required of it, and that

is to stop combustion. In this connection I take the liberty of repeating the results of some computations which I recently used in an article elsewhere.

The burning of material is simply the rapid oxidation which takes place when such material is raised to its ignition point in the presence of a supply of oxygen; and the combustion can be stopped only by removing one of these two essential conditions.

The combustion of one pound of wood will produce 7,200 thermal units, and such combustion can be stopped by an amount of water which will absorb enough of the quantity of heat to reduce the temperature of the wood to below its ignition point, the smallest quantity of water being that which will be evaporated by the fire. To evaporate one pound of water at a temperature of 60° requires 1,119 thermal units; and, therefore, the amount of heat generated by the combustion of a pound of wood is sufficient to evaporate 6·43 pounds of water, and this is the minimum amount of water which will stop the combustion.

As a practical matter it requires the application of a much larger quantity of water to extinguish a fire. If the temperature of the water was increased 40° by the heat of a fire, 180 pounds of water would be required for every pound of burning wood. A fire in a cotton picker-room was successfully put out by automatic sprinklers fed by an elevated tank, and it was found that 107¾ pounds of water were used for each pound of cotton burned. The floors of all buildings, with the exception of dwellings, contain enough fuel in each floor to evaporate water to a depth of two to three feet upon the floor, without any reference to the combustible contents of the buildings.

In the great fire at Lynn, November 26, 1889, enough water was used to cover the burned area of forty acres to a depth of seven feet; and in the fire at Boston two days later, the amount of water used was sufficient to flood the area to a depth of 12 feet 7 inches.

Mr. Charles B. Brush, C.E., stated, in a paper read before the American Society of Civil Engineers (*Transactions*, vol.

xix, p. 110), that 100,000 to 150,000 gallons of water were used at the general average of dwelling-house fires.

The conclusion to be drawn from these facts coincides with the well-known result of experience, that a fire must be extinguished in its early stages or destructive results will ensue. The fire department should be summoned at once in case of fire, unless one is positively certain that the means at hand will surely extinguish the fire, and no chances should be taken, especially if the fire has penetrated any hollow spaces in the building. Few persons have a proper appreciation of the skill, the bravery and the ingenious appliances of city fire departments.

The importance of a public water supply was appreciated at Philadelphia at an early day, and great wisdom was shown in the pioneer work connected with the Fairmount water supply. But the increase in the height of the buildings, their greater area, and the peril of continuous exposures have largely increased the necessities of water supply in all cities above what would have been thought ample a generation ago.

The first fire engine in America was made by Joseph Jenks, at the Saugus Iron Works, in accordance with the vote passed at the Boston town-meeting, March 1, 1653, after a large fire, ordering that "The Select (men) have power and liberty to hereby agree with Joseph Jynks for Ingins to convey water in case of fire if they see cause so to do."

The use of private fire apparatus has, in good hands, given excellent results; but fire apparatus, like all other possessions, needs care—even fire pails must be kept full—and unless such fire apparatus receives proper care it is worse than none.

Automatic sprinklers have given the best results of any private apparatus next to fire pails. As to their efficiency for mercantile risks, Messrs. Anderson & Stanton, insurance agents of New York, who make a specialty of underwriting upon such protected property, state that from January 1, 1887, to January 1, 1891, they have written $19,169,105 on this class of buildings, receiving as premiums $215,840; and during this time they have suffered losses to the amount

of $7,689 in twenty-five fires which have occurred—this amount being about three and one-half per cent. of the premium.

These results are even better than those of another insurance company, underwriting for the most part on manufacturing property protected by automatic sprinklers, where the results of thirteen years' experience show that the average loss on fires starting under automatic sprinklers, where these devices formed a part of the apparatus in service, amounts to one-eighteenth the average loss on fires under other apparatus than automatic sprinklers.

An exaggerated opinion of the efficiency of automatic sprinklers should not be based upon these results, as there have been instances, and will be many others, where the water is shut off either by malice or accident; and under exposure to processes generating corrosive fumes automatic sprinklers will undoubtedly be disabled by corrosion, although there is a wide difference between the various types of sprinklers in this respect.

In answer to a request for the best method of protecting certain buildings in Boston which were exposed to an excessive conflagration hazard, roof hydrants were suggested by an officer of an insurance company that was not interested, because it did not write upon city risks. These hydrants were placed in accordance with the suggestion, and the great fire in that city, November 28, 1889, was stopped in one direction by water supplied, at the rate of 2,500 gallons per minute, by private fire pumps, and poured from these roof hydrants upon burning buildings which had fallen, burying men and apparatus, and blocking the street in such a way as to prevent the use of the city fire apparatus at these points.

Such roof hydrants are worthy of more general application in city risks, and if surmounted by monitor nozzles, which will remain in any position in which they are placed, they could continue to do good service even after the smoke and flames had driven persons away from the roof.

All of this private fire apparatus tends to economize the city water supply, because of the efficient manner in which

water can be applied by such means at the early stages of a fire.

The general tendency of the management of city water works has been against private fire apparatus, although the experience on this matter has been of an opposite nature. Such apparatus, however, should not be connected to a public water supply, except under the most careful regulations.

Conclusion.—The adoption of any of the protective measures presented in this paper will fall short of the desired results, unless the community in general throws off its apathy in regard to the fire loss, and with a thorough realization of the easily preventable nature of much of this great waste, becomes interested in creating a public sentiment that will make a demand for conditions of safety.

Insurance rates in the cities are double what they should be, although they do not give a sufficiently remunerative income upon the capital invested in insurance, because the fire losses are so much greater than what they should be.

Major George S. Merrill, Insurance Commissioner for Massachusetts, states, in his report for 1890:

"It is within bounds to say that ninety per cent. of all fires arise from causes absolutely within the power of the individual to prevent." (*Thirty-fifth Annual Report of the Insurance Commissioner of Mass.*, p. 20.)

The fire hazard of a city abounding in humanity, and with a concentration of property, is a contingency terrible to contemplate, and would indeed be far more terrible in its realization were it not for the wonderful skill and bravery of fire departments in coping against the unequal odds of continuous combustibility.

This question is one of the greatest problems of municipal government, and does not its true solution lie in strengthening the hands of the administration of the fire departments by also giving them ample power in the matter of preventing fires by assigning to them inspection duties, such as have already proved to be so valuable in the hands of insurance organization, and would no doubt be even more efficient in the hands of persons acting under suitable authority of the law?

The same reasons apply to the organization of protective departments, which are now for the benefit of all sufferers by fire, but like the inspection corps maintained by private organization.

It will be for others to say how far individual rights under the law may prevent compulsory changes in existing buildings; but the building laws which are needed in cities are those which would apply to existing buildings rather than those regulating the construction of new buildings.

The whole question of the reduction of the conflagration hazard is one of possibilities, and this hazard can be reduced by general action on the part of any municipality to any extent that is demanded by general public opinion.

NEW ALLOYS AND THEIR ENGINEERING APPLICATIONS.

By F. Lynwood Garrison.

[*A lecture delivered before the Franklin Institute, January 30, 1890, and February 6, 1891.*]

[*Concluded from p. 129.*]

"The enormous elongations reported may give a greatly exaggerated notion of the metal's ductility. A test bar of iron or carbon steel undergoes a certain amount of elongation over its whole length, but much of its elongation occurs just at and near the point of rupture, where the metal 'necks.' It is owing to this that the percentage of elongation of short iron test bars is so much greater than that of long ones. Manganese steel, however, like brass, stretches more nearly uniformly over its entire length, without much necking. Its elongation would exceed that of equally strong carbon steel, much less if measured over a length of one-eighth of an inch, than if, as now, measured over eight inches. Now, elongation is indeed an index of toughness and ductility; but the relative toughness of different metals, under given conditions, can be safely inferred from their elongations only when these elongations occur in like man-

ner. For certain conditions it may be better, for others worse, that the elongation should be distributed as in manganese steel, rather than concentrated, as in carbon steel. But, while we may dispute whether the toughness of manganese steel of twenty-five per cent. elongation is, on the whole, greater or better, rather than worse than that of carbon steel of like elongation, the important point remains that it has a different toughness, which does not necessarily fit the metal for the purposes to which carbon steel of twenty-five per cent. elongation is properly put." "Thus, Stromeyer found that manganese steel, whose elongation under tensile stress led him to expect that it could be bent back and forth many more times before rupture than wrought iron, and carbon steel was actually rather more brittle when tested in this way, enduring only seven bendings when in its natural state, and from ten to eighteen after quenching from redness, while wrought iron and carbon steel endured in four cases 20, 26, 12·5 and 21 bends."

"Again, the results in Table IV show that, while the shock-resisting power of manganese steel of 12·55 per cent. of manganese is much greater than that of the best carbon axle steel with which it was compared, yet in spite of its enormous elongation under static tensile stress, its ultimate deflection on rupture, under transverse shock, is less than half as great as that of carbon steel."

EFFECT OF TRANSVERSING SHOCK ON MANGANESE AND CARBON STEEL. *Hadfield.*

	Energy Developed in Foot Tons.	Sum of Permanent Deflections. Inches.	
		Special Carbon Steel Axle.	Manganese Steel Axle.
At the 5th blow, ...	79·883	24·953	8·501
" 10th "	208·531	66·188	19·403
" 15th "	348·591	105·248 broke.	30·212
" 20th "	497·988	—	39·491 broke

Bars 4½″ in diameter and 4′ 6″ long, on bearings 3′ apart, were struck by a 20·75 cwt. ram, and reversed after each blow.

Manganese steel is usually made by adding ferro-manganese to molten Bessemer or open-hearth steel in a ladle.

MANGANESE AND SILICO-MANGANESE STEEL SHOWN AT PARIS BY HOLTZER. *Howe.*

Number.	Per Cent. of Manganese.	Tensile Strength. Pounds per Sq. In.			Elastic Limit. Pounds per Square Inch.			Elongation. Per Cent. in 7·9 Inches.			Contraction of Area. Per Cent.		
		Natural State (forged).	Oil-hardened and Tempered	Oil-hardened and Annealed.	Natural State (forged).	Oil-hardened and Tempered	Oil-hardened and Annealed.	Natural State.	Oil-hardened and Tempered	Oil-hardened and Annealed.	Natural State.	Oil-hardened and Tempered	Oil-hardened and Annealed.
1	·20@·30	83,488	—	—	42,668	—	—	22	—	—	42	—	—
		—	146,210	—	—	109,230	—	—	12·5	—	—	45	—
		—	—	112,075	—	—	91,026	—	—	13	—	—	38
2	—	87,612	—	—	49,210	—	—	14	—	—	—	—	—
		—	149,107	—	—	110,227	—	—	11·8	—	—	46	—
		—	—	131,134	—	—	98,706	—	—	10	—	—	46
3	—	97,710	—	—	46,366	—	—	20·8	—	—	42	—	—
		—	154,175	—	—	119,756	—	—	8·5	—	—	36·5	—
		—	—	161,571	—	—	129,285	—	—	13	—	—	40
4	—	107,382	—	—	57,033	—	—	16	—	—	35·5	—	—
		—	163,277	—	—	133,409	—	—	10	—	—	41	—
		—	—	141,232	—	—	122,600	—	—	11·8	—	—	43·5
5	—	102,546	—	—	57,034	—	—	19	—	—	51	—	—
		—	175,651	—	—	146,210	—	—	7·5	—	—	31	—
		—	—	154,175	—	—	133,409	—	—	8·5	—	—	45
6	10 ±	98,706	—	—	55,042	—	—	23·5	—	—	42·2	—	—
		—	176,363	—	—	155,882	—	—	8	—	—	31	—
		—	—	148,201	—	—	121,605	—	—	11·5	—	—	40
7	12@14	115,631	—	—	58,882	—	—	29	—	—	26	—	—
		—	122,316	—	—	61,869	—	—	28	—	—	28·5	—
		—	—	137,107	—	—	52,908	—	—	41·5	—	—	36·5
8	—	51,202	—	—	38,970	—	—	36	—	—	73	—	—
		—	87,328	—	—	63,575	—	—	15	—	—	76	—
		—	—	68,553	—	—	52,197	—	—	24·5	—	—	72·5
9	—	96,572	—	—	47,219	—	—	14	—	—	21	—	—
		—	139,098	—	—	19,200	—	—	10·5	—	—	42·2	—
		—	—	128,289	—	—	100,555	—	—	11·2	—	—	46
10	—	91,026	—	—	44,517	—	—	21·5	—	—	42·2	—	—
		—	159,580	—	—	118,763	—	—	13	—	—	38·5	—
		—	—	133,409	—	—	104,538	—	—	10·5	—	—	46
11	2 ±	92,021	—	—	47,504	—	—	23	—	—	50·5	—	—
		—	161,571	—	—	139,098	—	—	10	—	—	38·5	—
		—	—	146,210	—	—	121,605	—	—	12·5	—	—	46

The "natural state" pieces are simply cooled slowly after forging.
The oil-hardened and tempered pieces are quenched in oil from about W, a low yellow and slightly reheated.
The oil-hardened and annealed pieces are similarly quenched, then reheated to very dull redness, say V, and cooled slowly.

It is less desirable to mix them in crucibles on account of the strong corroding action of the manganiferous slag. The steel usually contains on analysis 0·5 per cent. less manganese than the amount added in the ferro-manganese.

The chemical reactions taking place in the manufacture of manganese in steel are probably very much the same as those taking place in the manufacture of manganese bronze. The dissolved oxide of iron present in the steel is deoxidized by the manganese in the same way as the dissolved cupreous oxide present in the metallic copper is deoxidized in making manganese bronze. The dissolved oxide of iron is promptly reduced by the manganese, forming a double silicate of iron and manganese, which readily slags off.

In the Bessemer and open-hearth processes of making steel, the metal under ordinary conditions becomes somewhat oxidized. Manganese is then usually added at the completion of these processes in the form of a manganiferous cast iron (spiegeleisen or ferro-manganese). This reduces the iron oxide, and in turn is itself oxidized and scorified.

Again, the presence of manganese in solidified steel appears to hinder its oxidation in heating and forging. The reaction of forming a double silicate of manganese and iron in molten steel seems to perform another function. It appears that molten steel usually contains minute mechanically suspended particles of slag, which cause "red-shortness." This suspended slag unites with the silicate so formed, rises to the surface and is fluxed off. The presence of manganese is very useful in steel by counteracting the red-shortness caused by the presence of sulphur, and in some cases it actually removes this metalloid from iron, sometimes (probably because sulphide of manganese like sulphide of calcium is less soluble in metallic iron than is sulphide of iron) by forming some compound rich in sulphur and manganese which liquates off, and perhaps carrying oxygen to the sulphur.*

* Howe's *Metallurgy of Steel*, p. 43.

The extreme point of brittleness of manganese steel occurs in the material containing from four to five per cent.; above this a slight increase in strength takes place; but even at about six and one-half per cent. it will only stand the same transverse test as cast iron.

Another singular point is that the carbon in such brittle samples is not over 0·3 to 0·5 per cent. or very little more than in mild steel. In fact, it has been noticed that the more purely the alloy consists of iron and manganese, the more brittle the product. According to Hadfield,* a piece of manganese steel heated sufficiently to be seen red hot in a dark place, on being plunged into cold water becomes soft enough to be easily filed, planed or otherwise fitted. Hardness is then restored by reheating to a bright red, and cooling in air. This kind of steel is especially useful for cutters for boring out bosses of wheels.

The maximum amount of manganese that may be present in low grades manganese steel before the steel becomes absolutely brittle, seems to be about two and one-half per cent.† The peculiar brittleness and extreme hardness begins to disappear at about seven and one-half per cent. manganese. Cast car wheels of manganese steel will usually outwear four or five ordinary ones.

Extremes of atmospheric heat and cold do not appear to affect the properties of the best grades of manganese steel.

When manganese steel contains from seven to twenty per cent. manganese, especial care must be taken not to overheat the ingots, or they will "burst" when under the hammer. This grade usually works well, is hard and close, rolls well, can be sheared when red hot; but does not weld properly.

In analyzing manganese steel no trace of graphite has been found, all the carbon present being in the combined form.

The ordinary crucible steel process is not only unsuitable for making manganese steel, on account of the manganese

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* *Proceedings of the Institute of Civil Engineers*, vol. xciii.

† R. A. Hadfield, in *Proceedings of the Institute of Civil Engineers*, vol. xciii.

slagging and cutting out the pots, but, on account of more or less carbon being taken up from the graphite in them. Manganese steel seems to be especially useful for car-wheels, on account of its combined hardness and toughness; and bed-plates of dynamos owing to its low magnetic susceptibility.

It has not been found serviceable for armor plate, probably owing to its relative low crushing strength in resisting penetration by projectiles, its extreme hardness in resisting abrasion must not mislead us in this respect.

At present its use is very much restricted by the extreme difficulty in its machining and forging. These difficulties and its liability to crack in quenching led some of the large steel works in France to wholly abandon any serious attempts to use it for armor plate.*

Its combination of great ductility and tensile strength should give it many important uses, while its remarkable combination of ductility and certain kinds of hardness is unsurpassed.

The alloy has been applied to the manufacture of tools with very good results. It is simply necessary to cast the metal into shapes, and grind it.

Couplers of the vertical plane type have also been cast of it, and the inventor (Mr. R. H. Hadfield, of Sheffield,) gives extremely interesting tests of the amount of work required to bend one of these couplers when subjected to the same kind of shock which they would receive in coupling cars. The best sample coupler contained 14·50 per cent. manganese, had been water-toughened, and stood a total energy of 320·87 foot-tons, with a total set in jaw of 0·65 inch, and was still unbroken. An American malleable iron coupler, tested in same way, was subjected to total work of 43·37 foot-tons, with a total set of 0·90 inch, and was broken.†

The exceptional hardness of manganese steel, together with its great ductility and strength, make it unsurpassed for the manufacture of steel tires and axles. Its applica-

* Howe's *Metallurgy of Steel*, p. 365.

† *Report of Science and Arts Committee of Franklin Inst.*, Nov. 18, 1890.

tion in the arts would doubtless be much more extensive were it not for its intense hardness; such difficulties, however, are mechanical, and it seems likely, in the course of time, they will be overcome in one way or another. When manganese steel can be made by the simple addition of metallic manganese and the simultaneous addition of iron and carbon, as is at present the case, avoided, we may expect even better results.*

Nickel Steel.—The subject of nickel and steel alloys was first brought to the attention of the engineering world by Mr. James Riley, of Glasgow, in a paper read by him before the British Iron and Steel Institute, at their meeting in May, 1889.† Quite recently the subject has acquired much greater notoriety, owing to the results of armor-plate tests lately made at Annapolis. In these tests nickel steel was shown to be superior to simple steel (carbon steel) and compound plates.

Apparently from no other conclusive investigations or tests than these, the United States Navy Department has decided to use nickel steel exclusively for armor plate. It seems to me the wisdom of this policy is very questionable and short-sighted, in view of some of the remarkable results which have been obtained with other and cheaper steel alloys.

In 1889 M. Henry Schneider, of Creusot, France, took out two patents for the manufacture of alloys of cast iron and nickel and steel and nickel, respectively.‡

In the specifications of the first patent, it is stated that it is very diffcult to incorporate nickel with iron and steel, particularly when it is attempted to produce these alloys on a commercial scale. "To overcome this difficulty, a preliminary product is made of cast iron and nickel in a crucible, cupola, or open-hearth furnace. This product or alloy, while specially useful for the manufacture of iron

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* The only difficulty in the way of using metallic manganese is its great cost.

† *Journal*, No. 1, 1889, p. 45.

‡ U. S. Patents 415,657 and 415,655, Nov. 19, 1889.

TENSILE TESTS OF NICKEL STEEL. *J. Riley.* (*a*)

Number.	Composition. Nickel.	Carbon.	Manganese.	Tensile Strength. Lbs. per Sq. In. As Cast.	Cast and Annealed.	Rolled.	Rolled and Annealed.	Elastic Limit. Pounds per Sq. In. As Cast.	Cast and Annealed.	Rolled.	Rolled and Annealed.	Elongation. % in 8 Inches. As Cast.	Cast and Annealed.	Rolled.	Rolled and Annealed.	Elongation. % in 4 Inches. As Cast.	Cast and Annealed.	Rolled.	Rolled and Annealed.	Contraction of Area %. As Cast.	Cast and Annealed.	Rolled.	Rolled and Annealed.
1	1·0	·42	·58	(*b*)	—	—	—	(*b*)	—	—	—	(*b*)	—	—	—	—	—	—	—	(*b*)	—	—	—
				—	122,304	—	—	—	67,152	—	—	—	—	—	—	—	1·5	—	—	—	9·5	—	—
				—	—	129,024	—	—	—	71,904	—	—	—	—	—	—	—	11·0	—	—	—	24·0	—
				—	—	—	123,424	—	—	—	67,424	—	—	—	—	—	—	—	14·7	—	—	—	45·0
2	2·0	·90	·50	*Unmachinable.*																			
3	3·0	·35	·57	78,176	—	—	—	41,352	—	—	—	—	—	—	—	2·5	—	—	—	5·6	—	—	—
				—	78,176	—	—	—	53,760	—	—	—	—	—	—	—	2·5	—	—	—	9·0	—	—
				—	—	114,240	—	—	—	70,336	—	—	—	—	—	—	—	20·3	—	—	—	37·0	—
				—	—	—	108,640	—	—	—	62,720	—	—	—	—	—	—	—	20·3	—	—	—	42·0
4	3·0	·60	·26	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
				—	—	115,360	—	—	—	65,856	—	—	—	9·0	—	—	—	10·1	—	—	—	9·0	—
				—	—	—	96,960	—	—	—	67,872	—	—	—	7·5	—	—	—	9·0	—	—	—	12·0
5	4·0	·85	·50	*Unmachinable.*																			
6	4·7	·22	·23	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
				—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
				—	—	90,720	—	—	—	56,224	—	—	—	17·75	—	—	—	23·4	—	—	—	42·0	—
				—	—	—	90,944	—	—	—	62,720	—	—	—	20·0	—	—	—	23·0	—	—	—	44·8
7	5·0	·30	·30	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
				—	—	103,936	—	—	—	67,200	—	—	—	10·0	—	—	—	12·5	—	—	—	22·5	—
				—	—	—	95,424	—	—	—	62,720	—	—	—	15·0	—	—	—	17·5	—	—	—	18·5
8	5·0	·50	·34	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
				—	—	116,480	—	—	—	69,664	—	—	—	14·0	—	—	—	15·6	—	—	—	14·0	—
				—	—	—	104,832	—	—	—	72,800	—	—	—	13·5	—	—	—	14·0	—	—	—	17·0
9	10·0	·50	·50	*Unmachinable.*																			
10	25·0	·27	·85	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
				—	—	115,136	—	—	—	85,568	—	—	—	10·5	—	—	—	11·7	—	—	—	—	—
				—	—	—	102,592	—	—	—	28,560	—	—	—	39·0	—	—	—	30·0	—	—	—	28·6
11	25·0	·82	·52	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
				—	—	106,624	—	—	—	49,280	—	—	—	43·5	—	—	—	47·6	—	—	—	60·0	—
				—	—	—	94,304	—	—	—	33,824	—	—	—	40·0	—	—	—	45·3	—	—	—	43·6
12	49·4	·35	·57	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
				—	—	83,776	—	—	—	45,920	—	—	—	—	—	—	—	12·0	—	—	—	24·0	—
				—	—	—	82,880	—	—	—	47,040	—	—	—	—	—	—	—	20·0	—	—	—	29·0
13	—	—	—	214,144				120,960				—				9·37				49·2			
14	—	—	—	219,831				116,302				7·8				—				52·4			
15	—	—	—	210,246				120,780				8·2				—				50·0			

(*a*) J. Riley, *Engineering*, May 17, 1889, p. 574, a paper read before the Iron and Steel Institute.
(*b*) Test-piece defective.
(*c*) Too hard to machine with Mushet's steel. Good tools may be made from it by quenching from dull redness in boiling water.
(*d*) The average is reduced by the low results given by one test-piece.
(*e*) Too hard to machine. Good cutting tools may be made from it by cooling in a blast of cold air.

and nickel and steel and nickel alloys, may be used as castings for a variety of purposes.

"In the manufacture of this alloy of cast-iron and nickel, a suitable furnace is charged with nickel scrap and ordinary cast or pig-iron, with carbonaceous matter; or the nickel may be in the form of nickelized compounds or coke. The operation is best carried on in a reverberatory furnace under a layer of anthracite, to avoid oxidation.

"The resulting alloy contains from five to thirty per cent. nickel, and is remarkable for its great elasticity and strength —properties which may be still further developed by chilling or tempering in the usual manner.

"This alloy of cast iron and nickel, containing (say) thirty per cent. of nickel, sixty-three per cent. of iron, three per cent. of carbon and two of manganese and silicon, is then charged on the bed of an open-hearth furnace, with the iron or scrap used in the ordinary methods of making open-hearth steel, care being taken to protect the bath from oxidation by means of a layer of slag or cinder. A steel, containing about five per cent. of nickel, is thereby obtained. Precautions, however, must always be taken to prevent red-shortness in the metal before the final introduction of the recarbonizing and manganiferous silico-spiegel iron or ferro-manganese.

"Nickel steel of this kind, containing five per cent. of nickel, is especially adapted or suitable for use in the construction of ordnance, armor plate, gun-barrels, projectiles and other articles employed for military or other like purposes, or the manufacture of commercial sheets, bars, etc.

"The percentages of carbon, silicon and manganese can be regulated according to the degree of hardness required, but in all cases, in order to obtain the best results possible, the product must invariably be tempered in an oil or other bath"*

What is known as "Marbeau's nickelo-spiegel" is made by a patented process, which consists in the reduction of the ores of nickel, iron and manganese at the same time and in

* U. S. Patent 415,655, Nov. 19, 1889.

one operation. The following proportions are stated as affording good results:*

Nickel ore or matt, containing ten per cent. of nickel, . .	2 tons
Manganese ore, containing ten per cent. manganese and forty per cent. iron, ...	1 ton
Iron ore, containing fifty per cent. iron, ...	12 cwt.

An alloy of nickel and iron having thus been obtained, there appears to be but little difficulty in working this nickel iron into a nickel steel by means of an open-hearth furnace.

Riley states the alloy (nickel steel) can be made in any good open-hearth furnace, working at a fairly good heat.† No special arrangements are required for casting, the ordinary ladles and moulds being sufficient. If the charge is properly worked, nearly all the nickel will be found in the steel—almost none is lost in the slag.

No extraordinary care is required when reheating the ingots for hammering or rolling. If the steel has been properly made, and is of correct composition, it will hammer and roll well, whether it contains little or much nickel. Riley‡ appears to have obtained the best results with steel containing five per cent. nickel. With this grade rolled, but not annealed, he obtained elastic limit 69,664 pounds per square inch, tensile strength 116,480 pounds per square inch, with fourteen per cent. elongation in eight inches. When rolled and annealed, elastic limit 72,800 pounds per square inch, tensile strength 104,832 pounds per square inch with thirteen and one-half per cent. elongation in eight inches.

Riley states that the whole series of nickel steels up to fifty per cent. nickel takes a good polish and finish. Steels rich in nickel are practically non-corrodible, and those poor in nickel are much better than other steels in this respect.

The alloys up to five per cent. of nickel can be machined

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* *Engineering and Mining Journal*, Jan. 31, 1891. See U. S. Patent 419,274; also British Patents 2,573 of 1884, and 7,179 of 1885.

† *Journal of the Iron and Steel Institute*, No. 1, 1889, p. 45. *Journal of the Franklin Institute*, May, 1890, p. 367.

‡ *Ibid.*, p. 48.

with moderate ease, beyond that they are more difficult to machine.

The one per cent. nickel steel welds fairly well, but this quality deteriorates with each addition of nickel.*

J. F. Hall, of Sheffield, states that he has made nickel steel with as much as ninety-seven tons per square inch (217,280 pounds) tensile strength, and over seven per cent. elongation.†

Mr. G. J. Snelus states that one of the remarkable peculiarities of nickel steel was that the extension of some of the specimens appeared to be uniform over the whole length. This is probably accounted for by the fact that nickel is closely allied in its nature to iron.‡

Alloys of iron and other metals are very apt to be unsound and the test pieces usually give way at their weakest points; frequently the rupture takes place locally, and the extension only over a particular area.

The tests of some of the nickel steel recently made by Carnegie, Phipps & Co., Pittsburgh, for the U. S. Navy Department, gave the following results: elastic limit (two specimens) 59,000 and 60,000 pounds per square inch, ultimate tensile strength 100,000 and 102,000 pounds per square inch, elongation fifteen and one-half per cent., and reduction of area at fracture twenty-nine and one-half and twenty-six and one-half per cent. The test pieces were cut from three-fourths-inch plate. The chemical analysis gave a content of three-sixteenths per cent. nickel.§

Howe states|| that the hardness of nickel steel depends on the proportion of nickel and carbon jointly, nickel up to a certain percentage increasing the hardness, beyond this lessening it. Thus white steel, with two per cent. of nickel and 0·90 per cent. of carbon cannot be machined. With less than five per cent. nickel it can be worked cold readily, provided the proportion of carbon be low. As the propor-

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* *Journal of the Iron and Steel Institute*, No. 1, 1889, p. 52.

† *Ibid.*, p. 58.

‡ *Ibid.*, p. 59.

§ *Engineering and Mining Journal*, Dec. 13, 1890.

|| *Metallurgy of Steel*, pp. 370, 371.

tion of nickel rises higher, cold-working becomes less easy. According to Howe, it forges easily whether it contain much or little nickel.

The presence of manganese in nickel steel is most important, as it appears that without the aid of manganese in proper proportions, the conditions of treatment would not be successful.

Nickel steel does not seem to be nearly so liable to corrosion in salt water as the ordinary and purer grades of steel. It might be observed in this connection that the corrosive action of salt water is much greater on ordinary steel than on the more impure qualities of iron.

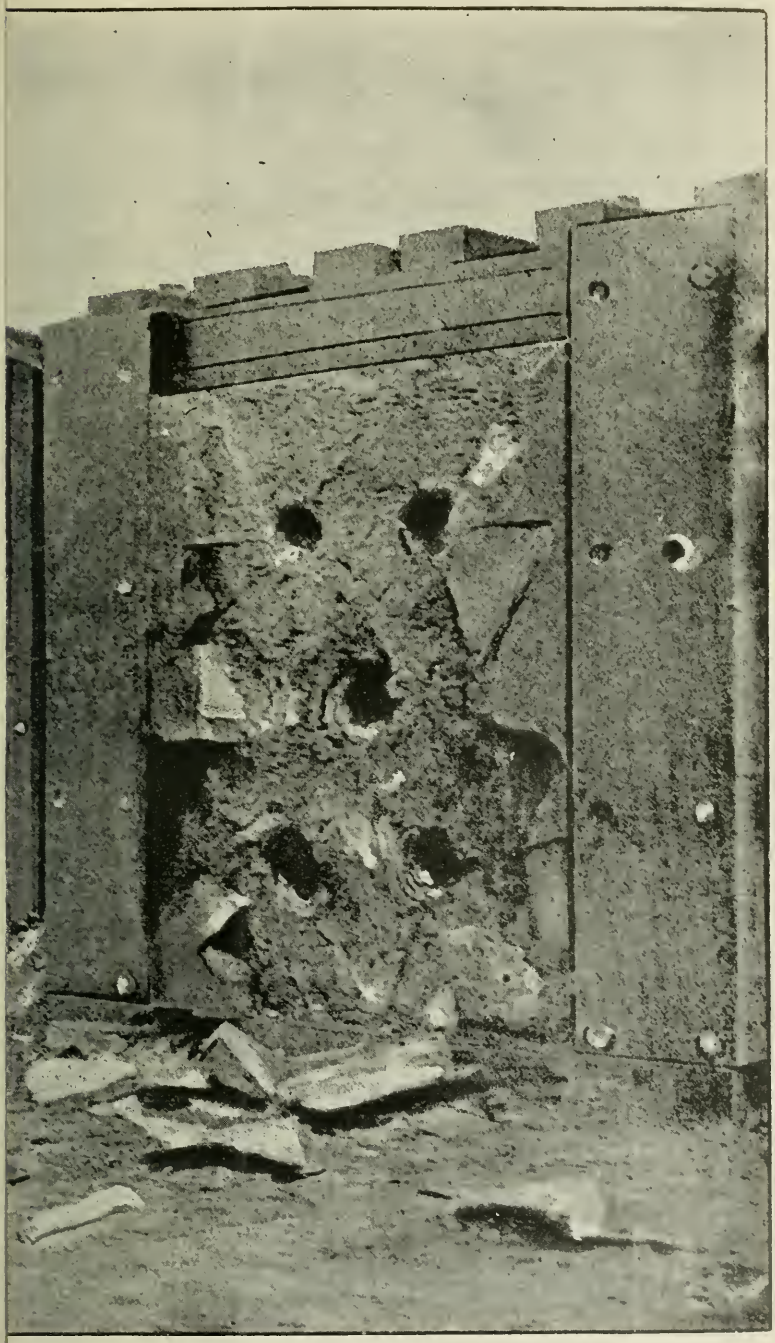
Nickel steel would, therefore, seem to be a great advance, as it appears to combine the splendid qualities of mild steel for structural purposes with a greater limit of elasticity and less corrodibility than either ordinary steel or iron.

Ship owners obtained, by the use of mild steel in the construction of ships, an advantage represented by a saving of twenty-five per cent. of fuel. Now if nickel steel will give a material of (say) thirty per cent. more strength, this reduction of fuel will be yet further increased.

Electrical Properties.—The conductivity of nickel steel is extremely poor and low, but the resistance very high. According to Hopkinson, nickel steel, containing less than five per cent. nickel, is decidedly more magnetizable than wrought iron, particularly for high inductions. On the other hand, when containing twenty-five per cent. nickel, it is non-magnetic. But if cooled to —20° C. (—4° F.), it becomes very decidedly magnetic and remains so when it again returns to its normal condition. If, finally, it is heated until it reaches its critical temperature, 580° C. (1076° F.), it becomes again non-magnetic and remains so until cooled to —20° C.

The success of the nickel-steel armor plate at the recent tests at Annapolis, have had, and will probably continue to have, a most important influence upon the manufacture of nickel steel, but whether the results then obtained justify the popular great expectations of this alloy remains to be seen.

(*Garrison.*)



ound Armor Plates.

The Creusot Steel, Nickel Steel, and the Cammell Compound Armor Plates.

A similar series of tests were made at Ochta, near St. Petersburg, Russia, November 11, 1890. Three 8 x 8 feet x 10-inch plates were tested; they were made by the well-known firms of Brown, Vickers (both English) and Schneider, of Creusot, France.* It was not known for certain whether the latter plate contained any nickel—probably it did not. Such being the case, these tests have no especial interest in this connection.

In *Fig. 7* we have a reproduction from a photograph of the plates tested at Annapolis, taken after the completion of the tests. There were three plates in all; an ordinary Creusot steel plate shown on the left, a Creusot nickel-steel plate in the centre, and a compound Cammell† plate on the right.

Four six-inch chrome steel projectiles (Holtzer) were fired at each, then the tests were completed by firing one eight-inch Firth shell at the centre of each plate.

All the projectiles perforated the compound plate and lodged in the backing. None of them perforated the steel plate; they either remained lodged in it, or else rebounded entire or in fragments. The plate, however, was cracked entirely through from top to bottom. Three of the projectiles lodged entire in the nickel-steel plate, the other two broke in fragments, their points remaining in the plate. The plate, however, remained entirely uncracked, although it showed slightly less resistance than the ordinary steel plate.‡

Silicon Steel.—For a number of years past it has been a common belief that steel, or more particularly forged steel, should contain as small amount of silicon as possible. Any amount exceeding ·10 per cent., or at most ·20 per cent., was considered highly injurious to its strength and ductility. From recent investigations it now seems, provided the amount carbon present be very small, the considerable amounts of silicon present in such steel (constituting

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* *Engineer*, Nov. 21, 1890, p. 409.

† Made by Cammell & Co., Sheffield, England.

‡ *Report of Board*, Oct. 11, 1890.

the so-called "silicon steel") produce excellent results as to toughness and malleability.

The *rôle* which silicon plays in cast iron and in steel is a most interesting one, and, until quite recently, its action was not properly understood. According to the investigations of Keep * and Turner, white carbonaceous cast iron, which would invariably give porous and brittle castings, is made free from honeycombs, and possesses much greater strength by the addition of comparatively small amounts of silicon.

The exact condition with which silicon is combined with iron is still a matter of dispute. In general, its effect upon iron is to change the carbon from the combined to the graphitic state. The amount of silicon required to produce a strong cast iron depends greatly upon the condition in which the carbon exists in the iron to begin with. The amount and relative conditions of the carbon present is also, to a greater or less degree, regulated by the amount of silicon present. It is safe to consider, as a general rule, that an increase of silicon changes the combined carbon to graphitic, and *vice versa*.

After the introduction of the Bessemer process it was observed that a certain definite percentage of silicon in the pig iron employed was necessary in order to produce good steel. This proportion was upwards of 1·5 per cent. Gautier† states when silicon is introduced in certain definite proportions into liquid steel, it enables blowholes to be eliminated. The effect of the presence of silicon in the Bessemer process is that of allowing the temperature of the metal to be kept higher than is otherwise attainable. The intense heat developed by the burning of the silicon in the Bessemer converter causes the silica produced by its oxidation to remain in the bath and to retain all its heat, in which respect it differs entirely from carbonic oxide, which is the product of the oxidation of the carbon.

Turner states that the density of cast iron is decreased

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* *Journal of the Iron and Steel Institute*, No. 2, 1889, p. 226. British Association, 1888. *Trans. Am. Inst. of Mining Engineers*, vol. xvii.

† *Journal of the Iron and Steel Institute*, No. 2, 1886, p. 743 and 744.

with tolerable uniformity by the addition of silicon. Osmond, in his experiments to determine the "critical points of iron and steel," states that silicon is alloyed with the iron, but does not form with it any definite compounds.*

Silicon steel is made from a rich, siliceous pig iron, known as "ferro-silicon," in much the same way as manganese steel is produced from ferro-manganese. Ferro-silicon is practically a pig iron containing from seven to fourteen per cent. silicon, and of a very high grade in other respects. Silicon has a remarkable affinity for iron; recent investigations have shown that iron will combine with seven or eight times more silicon than carbon. This amount may be somewhat further increased with the presence of an unusual amount of manganese. Keep† found that the loss of silicon in remelting silicon irons was trifling. He also found that in alloying silicon irons with scrap or pig iron, deficient in silicon, the silicon is practically all retained in the mixture.‡

The amount of silicon present in silicon steel, with which the best results have been obtained, is about two per cent., and with about 0·19 per cent. of carbon.

It will be observed from the table that one and one-half to one and three-fourths per cent. silicon increases the limit of elasticity and raises the tensile strength, but does not impair ductility. A further increase in tensile strength, however, can only be obtained by this means at the expense of ductility. A slight increase above two per cent. of silicon possesses marked changes in the characteristics of the material. In this respect its action resembles that of carbon in contradistinction to the action of manganese. It will be observed that with 1·5 to two per cent. silicon present the material possesses twenty-five to thirty per cent. elongation; whereas, the same percentage of carbon in the iron would give a product barely malleable and with practically no elongation under tensile stress.

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* *Journal of the Iron and Steel Institute*, No. 1, 1890, p. 63.

† *Trans. Am. Inst. of Mining Engineers*, vol. xvii, p. 258.

‡ *Ibid.* p. 261.

Unlike manganese steel, no further addition of silicon will effect a return of strength. When the amount of silicon exceeds six per cent. the steel is red-short, will not forge but crumbles at a low heat, notwithstanding the small amount (0·25 per cent.) of carbon present.

It is, therefore, obvious that as the amount of carbon present increases, the point of malleability ceases with a much lower percentage of silicon.

Unlike carbon, silicon does not confer the property of hardening upon iron when dipped hot into a cooling medium. It resembles manganese somewhat in this respect.

According to Gautier* some splendid tools have been made at the Hecla Works, Sheffield, with steel containing 1·5 per cent. silicon and less than 0·5 per cent. carbon.

Gautier reports the following silicon steels as producing excellent results.†

	C.	*Si.*	*Mn.*	*P.*
1, ...	0·783	0·342	0·370	0·019±
2, ...	0·826	0·840	0·430	0·019±
3, ...	0·574	0·478	0·200	0·019±
4, ...	1·075	0·675	0·520	0·023±
5, ...	1·091	0·690	0·370	0·019
6, ...	1·114	0·684	0·40	—
7, ...	0·941	0·877	0·36	0·028
8, ...	1·050	0·299	0·41	0·015
9, ...	1·188	0·575	0·40	0·018

One of the effects of the silicon on steel is probably similar to that of manganese. The silicon reduces part of the oxide of iron present in the steel forming silica which combines with the remainder of the oxide of iron forming a silicate, which rises to the top and is fluxed off more or less completely according to its condition of aggregation.‡

It must not be supposed that silicon can take the place of carbon, the latter must always have the advantage of being more easily applied and of producing a material

* *Journal of the Iron and Steel Institute*, No. 11, 1889, p. 244.

† "Les Alliages Métalliques," excerpt *Bulletin Soc. Minerale*, 2d Ser., III, 1889, pp. 91–92.

‡ Howe's *Metallurgy of Steel*, vol. I, p. 41.

Analysis per Cent.					Modulus of Elasticity by Professor Kennedy, in lbs. per Square Inch.	Bending Test of Annealed Bars, ½″ wide by ¼″ thick.		Relative Hardness Determined by Professor Turner in Flat Bars, ½″ x ¼″.
Carbon.	Silicon.	Sulphur.	Phosphorus.	Manganese.		Test by Hadfield.	Test by Turner.	
·14	·24	·08	·05	·14	In —	—	—	—
—	·18	—	—	—	Tes —	—	—	—
—	·20	—	—	—	Tes —	Bent double cold.	Bent cold through 180°, radius ⅜″, perfect.	20
—	—	—	—	—	,160,000	—	—	—
·18	·79	—	—	·21	In —	—	—	—
—	·70	—	—	—	Tes —	—	—	—
—	·73	—	—	—	Tes —	Bent double cold.	Bent cold through 180°, radius ⅜″, perfect.	20
—	·87	—	—	—	—	—	—	—
—	—	—	—	—	,970,000	—	—	—
·19	1·60	—	—	·28	In —	—	—	—
—	1·60	—	—	—	Tes —	—	—	—
—	1·52	—	—	—	Tes —	Bent double cold.	Bent cold through 180°, radius ⅜″, perfect.	24
—	—	—	—	—	,600,000	—	—	—
·20	2·18	·06	·04	·25	In —	—	—	—
—	2·11	—	—	—	Tes —	—	—	—
—	2·13	—	—	—	Tes —	Bent double cold.	Bent cold through 180°, radius ⅜″, perfect.	24
—	—	—	—	—	,200,000	—	—	—
·20	2·67	—	—	·25	In —	—	—	—
—	2·69	—	—	—	Tes —	—	—	—
—	2·67	—	—	—	Tes —	Bent double, but broke in radius with last blow	Bent through 180°, but broke off sharp at bend.	26
—	—	—	—	—	,500,000	—	—	—
·21	3·46	—	—	·29	In —	—	—	—
—	3·39	—	—	—	Tes —	—	—	—
—	3·36	—	—	—	Tes —	Bent only to right angle, much stiffer.	Broke at 45°.	30
—	—	—	—	—	410,000	—	—	—
·25	4·49	—	—	·36	In —	—	—	—
—	4·18	—	—	—	Tes —	—	—	—
—	4·23	—	—	—	Tes —	Very brittle, would not bend at all.	Broke at 15°.	33
—	—	—	—	—	—	—	—	—
·26	5·53	·06	·04	·29	In —	—	—	—
—	4·9	—	—	—	Tes —	—	—	—
—	4·80	—	—	—	Tes —	Very brittle, would not bend at all.	Snapped in three pieces at first blow of hammer.	36
—	—	—	—	—	650,000	—	—	—
·04	7·23	—	—	·29	In —	—	—	—
·03	8·83	·07	·05	·68	In —	—	—	—

ALLOYS OF IRON AND SILICON.

Analysis per Cent.																			
Carbon.	Silicon.	Sulphur	Phosphorus.	Manganese.	Drilling taken from	How Ingot Forged.	Whether Tested in Annealed or Unannealed Condition.	Original Diameter (Inches.)	Limit of Elasticity in Tons per Square Inch.	Amount of Stretch in Inches at Elastic Limit	Breaking Load in Tons per Square Inch on Original Area	Total Extension Per Cent.	Reduction of Area Per Cent.	Appearance of Fracture of Test Bar.	Appearance of Fracture of Annealed Forged Bar from which Test Bar was prepared.	Modulus of Elasticity by Professor Kennedy, in lbs. per Square Inch.	Bending Test of Annealed Bars, ½" wide by ¼" thick. Test by Hadfield.	Bending Test of Annealed Bars, ½" wide by ¼" thick. Test by Turner	Relative Hardness Determined by Professor Turner in Flat Bars, 1" × ¼"
·14	·94	·08	·05	·14	Ingot.	Fairy well.	—	—	—	—	—	—	—	—	—	—	—	—	—
—	·18	—	—	—	Test bar	—	Unannealed.	·7979	22·00	·0065	33·00	30·05	54·54	Silky.	—	—	—	—	—
—	·20	—	—	—	Test bar.	—	Annealed.	·7979	15·17	·0095	25·00	37·55	60·74	Silky.	Mild and rather burnt.	—	Bent double cold.	Bent cold through 180° radius ⅜", perfect.	[illegible]
—	—	—	—	—	—	—	Annealed.	·898	15·17	—	23·44	16·9	42·7	Silky, but with a large reedy flaw.	—	30,160,000	—	—	—
·18	·79	—	—	·21	Ingot.	Very well.	—	—	—	—	—	—	—	—	—	—	—	—	—
—	·79	—	—	—	Test bar.	—	Unannealed.	·7979	25·00	·013	34·00	29·50	54·54	Silky.	—	—	—	—	—
—	·73	—	—	—	Test bar.	—	Annealed.	·7979	19·00	·0045	29·50	34·02	52·66	Silky.	Mild, close, granular.	—	Bent double cold.	Bent cold through 180°, radius [illegible]", perfect.	[illegible]
—	·87	—	—	—	—	—	Annealed.	·7979	19·00	—	28·50	25.45	42·56	Silky.	—	—	—	—	—
—	—	—	—	—	—	—	—	·898	18·16	—	27·49	26·5	66·4	Silky at edges, very finely granular at centre.	—	29,979,000	—	—	—
·19	1·60	—	—	·28	Ingot.	Very well.	—	—	—	—	—	—	—	—	—	—	—	—	—
—	1·60	—	—	—	Test bar.	—	Unannealed.	·7979	28·0	·008	37·5	31·10	50·58	Centre silky, outside finally crystalline.	—	—	—	—	—
—	1·52	—	—	—	Test bar.	—	Annealed.	·7979	25·0	·0045	33·00	35·10	54·52	Silky.	Mild, close, granular.	—	Bent double cold.	Bent cold through [illegible] radius [illegible]", perfect.	24
—	—	—	—	—	—	—	—	·898	23·09	—	32·5	24·3	58·3	Silky at edges, very finely granular at centre.	—	29.600,000	—	—	—
·20	2·18	·06	·04	·25	Ingot.	Very well.	—	—	—	—	—	—	—	—	—	—	—	—	—
—	2·11	—	—	—	Test bar.	—	Unannealed.	·7979	31·00	·004	39·5	18·48	28·02	Silky.	—	—	—	—	—
—	2·13	—	—	—	Test bar.	—	Annealed.	·7979	25·50	·006	34·0	36·50	59·96	Silky.	Granular, but crystals much larger.	—	Bent double cold.	Bent cold through 180°, radius [illegible]", perfect	24
—	—	—	—	—	—	—	—	·898	20·22	—	27·98	5·6	—	Broke in screw thread ('93" diameter), fracture somewhat coarsely crystalline.	—	26,200,000	—	—	—
·20	2·67	—	—	·25	Ingot.	Very well.	—	—	—	—	—	—	—	—	—	—	—	—	—
—	2·69	—	—	—	Test bar.	—	Unannealed.	·7979	32·0	·0065	42·5	17·6	24·36	Coarse and slightly granular.	—	—	—	—	—
—	2·67	—	—	—	Test bar.	—	Annealed.	·7979	24·0	·0052	32·0	6·05	6·64	Coarse and granular.	Coarse, open.	—	Bent double, but broke in radius with last blow	Bent through 180°, but broke off sharp at bend.	26
—	—	—	—	—	—	—	—	·898	23·5	—	28·52	2·5	—	Broke in screw thread ('93" diameter), fracture somewhat coarsely crystalline.	—	28,500,000	—	—	—
·21	3·46	—	—	·29	Ingot.	Very well.	—	—	—	—	—	—	—	—	—	—	—	—	—
—	3·39	—	—	—	Test bar.	—	Unannealed.	·7979	35·0	·01	47·5	11·10	14·22	Coarse and slightly granular.	—	—	—	—	—
—	3·36	—	—	—	Test bar.	—	Annealed.	·7979	30·0	·009	39·0	8·85	9·28	Coarse and granular.	Coarse, open.	—	Bent only to right angle, much stiffer.	Broke at 45°	30
—	—	—	—	—	—	—	—	·803	29·45	—	34·17	3·2	5·65	Entirely and somewhat coarsely crystalline.	—	28,410,000	—	—	—
·25	4·49	—	—	·36	Ingot.	Very well.	—	—	—	—	—	—	—	—	—	—	—	—	—
—	4·15	—	—	—	Test bar.	—	Unannealed.	·7979	45·0	·003	49·0	·004	·20	Coarse and slightly granular	—	—	—	—	—
—	4·23	—	—	—	Test bar	—	Annealed.	·7979	None visible.	—	38·0	·64	·98	Coarse and granular.	Coarse, open.	—	Very brittle, would not bend at all.	Broke at 15°.	33
—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
·26	5·53	·06	·04	·29	Ingot.	Very well.	—	—	—	—	—	—	—	—	—	—	—	—	—
—	4·9	—	—	—	Test bar.	—	Unannealed.	·7979	None visible.	—	48·0	·30	·70	Coarse and slightly granular.	—	—	—	—	—
—	4·86	—	—	—	Test bar.	—	Annealed.	·7979	25·0	·0075	25·0	·37	Broke in thread.	Broke in thread, coarse and granular.	Very coarse.	—	Very brittle, would not bend at all.	Snapped in three pieces at first blow of hammer.	36
—	—	—	—	—	—	—	—	·803	None visible.	—	38·98	·7	1·98	Entirely and somewhat coarsely crystalline.	—	28,650,000	—	—	—
·04	7·23	—	—	·29	Ingot.	—	—	No test bar made, would not forge.				—	—	—	—	—	—	—	—
·03	8·83	·07	·05	·68	Ingot.	—	—	No test bar made, would not forge.				—	—	—	—	—	—	—	—

more suited to the various requirements of all classes of engineers.

Some of the silicon steel alloys are at present of no practical use and have no other than scientific interest, but it is, of course, impossible to conjecture to what uses they might be put in the future or how their properties could be improved by various changes.

The electrical resistance of silicon steel is nearly as great as that of manganese steel or approximately from four to seven times that of iron.

Tungsten Steel.—Although the metal tungsten itself is infusible, it readily unites with iron, forming an alloy known as ferro-tungsten. In this form is used in the preparation of tungsten steel.

Formerly the oxide of tungsten was melted with Swedish or good hematite pig-iron drillings; the drillings or turnings being used to secure a better action between the carbon and the oxide of tungsten. The process is, therefore, similar to that of making ordinary steel, in which the manganese oxide and the tungstic oxide change places. Now, however, the steel is first melted, not carbonized, and ferro-tungsten of known composition added to the same. By this modification, its manufacture is much more under control and the products more uniform.

The general effect of tungsten on steel is to render it intensely hard and brittle. It is very difficult to forge, and it cannot be welded when the amount of tungsten present exceeds two per cent. It is, therefore, not only unfit for structural purposes, but also for tools subject to shock, such as rock drills, chisels, hammers, etc. Of course, the degrees of brittleness and hardness are dependent upon the amount of tungsten present in the steel. Some steels have been made very hard and also had their toughness increased with a small percentage of tungsten.

In 1844, the Duc de Luynes found that in nine analyses of oriental damasked steel, steel tungsten appeared in each. In six, but as a trace, whilst in the other two, one contained 0·518 per cent. and the other one per cent. of tungsten.*

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* Percy, *Metallurgy of Iron and Steel*, p. 189.

According to Chernoff, tungsten steel after a few heatings becomes oxidized and loses its special properties.

The use of tungsten steel seems to be increasing in France notwithstanding its high price (by reason of the scarcity of tungsten). The St. Chamond Company use it for springs, claiming it to possess a carrying power about one-third greater than the best carbon spring steel.

One peculiarity of tungsten steel is that in the absence of carbon it is not strengthened or increased in hardness by tempering. When the amount of tungsten present becomes considerable these steels can be worked only with the greatest difficulty. The higher grades cannot be cut by the file, and as none of it can be tempered, it must be shaped at one forging, and then ground to the form desired.

Tungsten steel is obviously especially useful for standard gauges, tools, etc. The presence of tungsten greatly increases the magnetism of steel, although, unlike nickel, it is not magnetic itself.

TUNGSTEN STEEL. *Howe.*

Source, etc.	Composition.						Tensile Strength. Pounds Per Square Inch.	Elongation. Per Cent.
	W.	Fe.	C.	Si.	Mn.	P.		
1. Schneider,	11·03	—	2·15	·26	1·49	·007	—	—
2. Mushet's special,	9·99	—	1·24	0·33	1·04	·04	—	—
3. " "	7·81	—	1·99	·09	·19	—	146,400	0
4. English,	8·25	—	1·70	0·82	1·26	—	—	—
5. "Crescent Hardened," Pittsburgh,	6·73	—	2·06	·05	2·66	—	76,100 *a* 94,000 *b*	0
6. "Imperial," Pittsburgh,	6·38	—	1·6	·16	2·11	—	—	—
7. " "	—	—	—	—	—	—	67,000 91,000	0
8. Ledebur,	8·81	—	·42	·76	2·57	—	—	—
9. "	8·74	—	·38	·76	2·48	—	—	—
10. Styrian,	6·45	—	1·20	·21	·35	—	190,000	0·75
11. Bochum,	3·05	95·85	—	—	tr.	—	—	—
12. "	2·71	96·37	—	—	tr.	—	—	—
13. "	1·94	—	1·43	·19	·44	—	—	—
14. De Fenffe,	—	—	—	—	—	—	153,300	—
15. "	—	—	—	—	—	—	166,500	—

1. L. Schneider, *Oest. Zeit.*, 1885, XXXIII, p. 257; *Journ. Iron and St. Inst.*, 1884, I, p. 230. 2. Hard English Mushet's Steel, *Metallurgical Rev.*, II, p. 441. 3. The same tested by Howe. 4. Ledebur, *Handbuch*, p. 263. 5. Made by Miller, Metcalf & Parkin, tested by Howe. 6 and 7. Made by Park Bros. & Co., and tested by Howe. 8, 9 and 10. Ledebur, *loc. cit.* 11 and 12. Percy, *Iron and Steel*, p. 194. 13. Ledebur, *loc. cit.* 14 and 15. *Rev. Univ.*, 1860, p. 88. *a.* As received from the makers. *b.* Quenched in oil from very dull redness.

Like chrome steel, tungsten tool steel can be worked easily at red heat, but to obtain the best results it must be handled with the greatest care.

TUNGSTEN STEEL. *Holtzer.*

Number.	Tensile Strength. Pounds per Sq. In.			Elastic Limit. Pounds per Square Inch.			Elongation. Per Cent. in 7·9″.			Contr ction of Area. Per Cent.		
	Natural State.	Oil-hardened and Temp'd.	Oil-hardened and Annealed.	Natural State.	Oil-hardened and Temp'd.	Oil-hardened and Annealed.	Natural State.	Oil-hardened and Temp'd.	Oil-hardened and Annealed.	Natural State.	Oil hardened and Temp'd.	Oil-hardened and Annealed.
1	68,553	—	—	47,504	—	—	23·7	—	—	75·5	—	—
	—	82,492	—	—	67,558	—	—	17·5	—	—	66	—
	—	—	76,092	—	—	52,197	—	—	19·5	—	—	72·3
2	71,114	—	—	50,348	—	—	23·5	—	—	60	—	—
	—	71,114	—	—	48,499	—	—	8·2	—	—	6	—
	—	—	93,017	—	—	—	—	—	15	—	—	59
3	77,941	—	—	41,672	—	—	23·5	—	—	45·1	—	—
	—	179,349	—	—	135,117	—	—	2·5	—	—	2·5	—
	—	—	116,769	—	—	90,172	—	—	10·2	—	—	40
4	93,017	—	—	47,504	—	—	17	—	—	33	—	—
	—	216,186	—	—	—	—	—	4·5	—	—	4	—
	—	—	134,406	—	—	104,538	—	—	8·5	—	—	24
5	106,386	—	—	62,580	—	—	9	—	—	—	—	—
	—	213,342	—	—	—	—	—	2·8	—	—	1	—
	—	—	140,806	—	—	109,230	—	—	8·3	—	—	27

The "natural state" pieces are simply cooled slowly after forging.
The "oil-hardened and tempered" pieces are quenched in oil from a low yellow heat and slightly reheated.
The "oil-hardened and annealed" pieces are simply quenched, reheated to very dull redness, and cooled slowly.

Tungsten steels are more durable than ordinary steels, but these advantages are in most cases more than offset by the difficulties and peculiarities in working them.

Tungsten is also used for self-hardening steels. Some of these, however, contain as much as two and one-half per cent. manganese, which is added to counteract the red-shortness of the tungsten.

It will be observed from the tables that the elongation of tungsten steel is very low where the tensile tests are very high; this affords excellent evidence of its extreme hardness and want of ductility.

This peculiarity might be considered as a general rule with alloys, for where we have a very high resistance to tensile stress the ductility is low. The aim, of course, in producing a material intended for structural purposes is to have both these factors as high as possible. In this connection it might be well to observe that the factor *elastic limit* is apt to be misleading, as no one can say where it begins or where it ends. It is my opinion that the uniformity with which the elongation and reduction of area takes place is a much more important factor in giving an indication of the ductility and general character.

According to Preece, tungsten raises the magnetic induction of steel from 700 to 5,000, whilst it raises that of nickel from 120 to 1,032. Three per cent. of tungsten makes nickel more strongly magnetic than the steel of which magnets were formerly made.

A CORRECTION.

To the Editor Journal Franklin Institute:

I find that in my lecture on "Induction of Electric Currents and Induction Coils," I have committed an error in the use of terms, which I desire to correct. I used the term "impedance," in the sense of opposing action of self-induction to alternating currents. In reality it is a much broader term and includes not only such self-inductive opposition, but the checking action of resistance also.

Yours truly, ELIHU THOMSON.

Lynn, Mass., August 17, 1891.

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THE STEAMLOOP.

BY WALTER C. KERR.

[*A lecture delivered before the Franklin Institute, February 27, 1891.*]

The lecturer was introduced by the Secretary of the Institute, and spoke as follows:

MEMBERS OF THE INSTITUTE, LADIES AND GENTLEMEN:

When your Secretary honored me with an invitation to address you, he suggested the acceptability of remarks on centralization of power for distribution—electrically, hydraulically, pneumatically, or any way—over large areas, etc. I considered this proposition only to conclude that it was a little broad for my calibre, for I think my personal inclination in choice of subjects may have been bored out rather small originally, and possibly has been "bushed down" since. At any rate, I would regard it as taking an

unfair advantage to discuss ways and means I never tried; to quote authorities I never knew; to explain what is done abroad, where I have never been, and what is going to be done in a future, of which I am not the prophet. Therefore, I have selected a subject so simple that it can become for an hour a personal matter between ourselves and the blackboard. Novelty is its chief claim for attention, but in it there is, perhaps, enough to be learned concerning new applications of old laws to repay the time spent, enough by way of peculiar phenomena to excite admiration, and possibly—at first sight—a little that seems paradoxical.

The steamloop is generally called an ingenious device, and if so, the ingenuity certainly appears at once in the name; "Steamloop," a name which, though almost meaningless, seems very consistent with its simplicity. The name has the further merit of not portraying any of its functions or peculiarities, and hence cannot be an embarrassing restraint, as is so frequently the case with names attached to mechanical apparatus.

That so simple an application of Nature's laws as is involved in the steamloop should not have been turned to useful effect earlier is, at first thought, strange, but as one looks deeper into the subject, the reasons become more apparent. While no engineer is unfamiliar with the phenomena on which it depends, it has been interesting to note that even those best informed in practical steam engineering or theoretical research in thermo-dynamic science, seldom understand its action on first acquaintance, though they soon recognize in it a new combination of functions.

Its mission is the simple and useful one of returning water of condensation to steam boilers. Its chief characteristics are that its action is continuous, rapid and positive, and that it is a closed system operating under widely varying conditions, without valves or adjustments. Its construction is simply that of ordinary piping.

The principles on which its action depends are as follows:

Difference of pressure may be balanced by a water column.

Vapors or liquids tend to flow to the point of lowest pressure.

Rate of flow depends on difference of pressure and mass.

Decrease of static pressure in a steam pipe or chamber is proportional to rate of condensation.

In a steam current water will be carried or swept along rapidly by friction.

To these simple statements there will probably be no dissent. We have all used them in many ways, and some of them have disagreeably used us in a manner quite unwelcome. But it remained for the steamloop to collect a

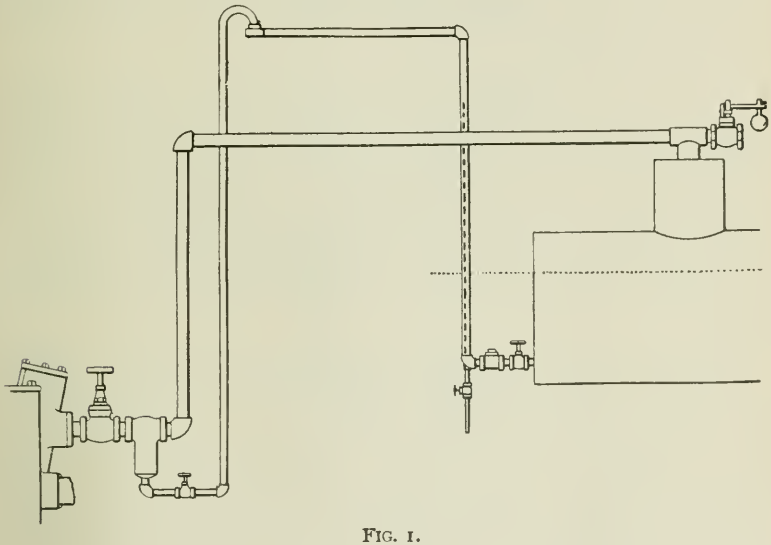


FIG. 1.

few of these erratic agents and from them create a useful system, combining the certainty of flow due to difference of pressure, with the quiet uniformity with which steam condenses, and with the force we see uselessly expended in the hammering of our steam-heating apparatus.

It will be evident that the steamloop, therefore, contains no mysterious factors, even though, like the steam injector, it has been called a paradox.

We have here a working model (see *Fig. 1*), the steam pipe passing from the boiler to a separator near the engine, which separates the water of condensation and entrainment

from the steam. The drip from the separator is below the boiler, and evidently were a pipe run from this drip outlet directly to the boiler, we would not expect the water to return up-hill. Moreover, the pressure in the boiler is (say) 100 pounds, while in the separator it is only ninety-five pounds, due to the decrease in pressure in the steam pipe by reason of which the steam flows to the engine. Thus the water must not only flow up-hill to the boiler, but also must overcome the difference in pressure. The device to return it must perform work, and in so doing heat must be lost. The loop therefore may be considered as a peculiar motor doing work, the heat expended being radiation from the upper or horizontal portion.

We are now prepared to examine its mechanical operation, which is best done with the model in action. The form of separator is immaterial, there being many kinds differing more or less in construction and efficiency. The one in model is simply an elbow turned down into the body of the device (see *Fig. 2*), throwing the steam against a perforated plate above which the dry steam is removed by a pipe leading to engine, while the water collects below.

From the separator drain leads the pipe called the "riser," which at a suitable height empties into the "horizontal." This leads to the "drop-leg," connecting to the boiler anywhere under the water line. The riser, horizontal and drop-leg form the loop, and usually consist of pipes varying in size from three-fourths inch to two inches, and are wholly free from valves, the loop being simply an open pipe giving free communication from separator to boiler. (For convenience stop and check valves are inserted, but they take no part in the loop's action.)

Suppose steam is passing, engine running and separator collecting water. The pressure of ninety-five pounds at the separator extends (with even further reduction) back through the loop, but in the drop-leg meets a column of water (indicated by the heavy broken line), which has risen from the boiler, where the pressure is 100 pounds, to a height of about ten feet. That is to the hydrostatic head equivalent to the five

pounds difference in pressure. Thus the system is placed in equilibrium.

Now, the steam in the horizontal condenses slightly, lowering the pressure to ninety-four pounds, and the column in drop-leg rises two feet to balance it, but meanwhile the riser contains a column of mixed vapor, spray and water, which also tends to rise to supply the horizontal as its steam condenses, and being lighter than the solid water of the drop-leg, it rises much faster. If the contents of the riser have a specific gravity of only ·1 that of the water in the drop-

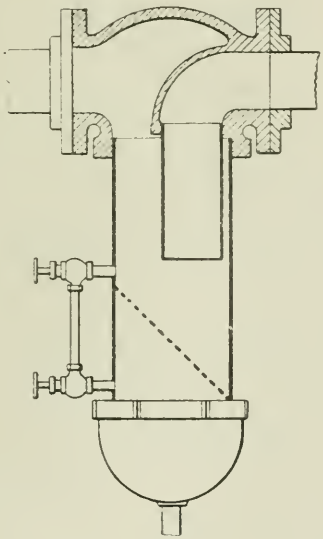


FIG. 2.

leg, the rise will be ten times as rapid, and when the drop-leg column rises one foot, the riser column will lift ten feet. By this process the riser will empty its contents into the horizontal, whence there is a free run to the drop-leg and thence into the boiler. In brief, the above may be summed into the statement that a decrease of pressure in the horizontal produces similar effects on contents of riser and drop-leg, but in degree inversely proportional to their densities. When the condensation in horizontal is maintained at a constant rate sufficient to give the necessary difference in

pressure, the drop-leg column reaches a height corresponding to this constant difference, and rises no further. Thus, the loop is in full action, and will maintain circulation so long as steam is on the system, and the differences of pressure and quantities of water are within the range for which the loop is constructed.

The above may be termed the rational explanation, but for simplicity we have omitted to include some of the features which are of importance in the loop's utility and which will appear later in our consideration of the subject.

"Solid" Water vs. Spray.—In the model the water sometimes appears as a film along the sides of pipes, or as spray, and often as slugs rising quickly and passing over. We cannot definitely state whether slugs form in practice in full size pipes, but their existence is doubtful except when the separator is partly flooded by boiler primage. In the model the pipes are so small that cohesion and capillary attraction are sufficient to account for the existence of the slugs. The resistance of small pipes causes comparatively slow velocity, and the slugs are readily seen. In the full-sized apparatus, however, the velocity is very great, so that even in glass sections a slug's passage would scarcely be discernible. Observations in this line indicate absence of slugs and confirm the belief that the water (other than spray) is carried chiefly by friction of steam current along the sides of pipes, and at a velocity so great that the sweep is distinctly audible when much water is moving.

No water should accumulate in the separator, as it is the mission of the loop to remove it before it assembles into a liquid mass. It is here that the constant and vigorous action is of great practical utility, enabling the loop to act as a preventive of accumulation rather than a device for removing water after it has accumulated. The separator evidently must be of such form as to give the sweep towards and through the loop better opportunity to pick up the entrained water than is afforded the current sweeping toward the engine, pump or steam-using device. It is interesting to know that experiments on very large separators, as large as 5 feet by 12 feet, not discharging their

contents, show that if water be allowed to accumulate to a certain height, no further rise will occur, even though much moisture be present, in the steam, showing that the steam sweeping through carries the water with it, unless that already deposited be drained away. Thus a separator to properly perform its function of drying steam must be empty, while obviously to stop and hold primage, its volume must not be impaired by periodic accumulations. Thus "solid" water in bulk is to be avoided. Condensation and entrainment should be retained and returned as spray or films, while primage should be broken up into particles or masses small as possible and instantly returned before a cumulative effect causes damage. In performing these functions the steamloop offers a new process in the apparently humble mission it serves.

That separators alone do not generally separate all the moisture from the steam is quite clearly shown by the fact that a loop will often return more water when the throttle is closed and the engine is idle, since the separator must then stop all moisture and the loop return it. With engine running, some moisture will always be carried over, the amount of course depending upon the efficiency of separator. Experiments on this feature are difficult because of the interference due to varying amounts of condensation, entrainment and primage, on all of which the draft of steam may have more or less effect.

Limitations.—Generally speaking, the limits within which the steam-loop is applicable are very wide, for the principle applies quite as well to great as to small differences of pressure. Similarly, an enormous quantity of water may be handled quite as easily as a small amount. The action will continue reliably through long pipes, overhead or underground. Water may be lifted from levels far below the boilers. The use to which the steam may be applied after the loop and separator have dried it, of course has no effect upon the loop system. Wherever steam is so used that it condenses rapidly, as in dryers, steam-heating systems, jackets, steam kettles, etc., the loop can be applied to the return of this water of condensation the same as from an

ordinary separator, and that, too, against any difference of pressure.

The above statements are made to illustrate how thoroughly and completely the loop can be applied to a wide range of conditions, but when we come down to the practical application, and say, how far is it expedient to apply it, the field contracts somewhat.

To take up the different limiting conditions, and comment upon their degree will show most clearly the practical range through which the loop may be made a commercial device.

Difference of Pressure.—The loop's application in this regard is limited most often by the head room for its erection. If the pressure in a separator, dryer, or return from a steam-heating system be ten pounds below the boiler, and a loop about thirty feet high is necessary to make the return, it is evident that a difference of fifty pounds in pressure would require a loop about 150 feet high and the riser, drop-leg and large portion of the horizontal being well covered with non-conductor, such a loop would operate efficiently, but generally speaking, a line of small pipe of that height would seldom be convenient, inasmuch as it would require some peculiar structure to hold it, or possibly, might need to be erected on the side of a smokestack. In high city buildings such a loop may be practicable where convenient air shafts allow easy support, but in ordinary manufacturing plants it would seldom be constructed.

While speaking of difference of pressure, attention should be called to the fact that the absolute pressure is of no importance, as a loop will work quite as well under low pressure as high. Its construction and operation recognize only the difference of pressure. A special case occurs, however, where the difference of pressure is very large compared with the lowest pressure in a system. For instance, if a boiler carries twenty-five pounds of steam and at the end of a series of heating or drying coils the pressure is one pound, then with a loop about 100 feet high it would be evident that if the condensation in the horizontal were so performed as to even produce a perfect vacuum, the water column in

drop-leg would stand about eighty feet high, but it is doubtful whether the pressure of one pound at foot of riser plus the 14·7 pounds due to vacuum would be sufficient to force the contents of riser up 100 feet and into the horizontal. It certainly would not be sufficient if there were considerable quantity of water to be handled, thus causing a high specific gravity of riser contents. Such case, however, is so seldom met in practical loop application, that it scarcely need be considered a limiting condition.

Roughly speaking, differences of ten to fifteen pounds are the largest experienced in good practice, and the loop can generally be conveniently erected to operate against such differences, and where excessive discrepancies in pressure are observed, it is usually very desirable to make such changes as will diminish differences, they being usually due to faulty piping. While, therefore, excessive difference of pressure is practically a limiting condition to steamloop practice, it is not found to be an annoying interference.

Distance of Foot of Riser below Water Level of Boiler.—Since the system is placed in equilibrium by the drop-leg column, and this starts from the boiler, no account need be taken of the distance the riser may extend below water level in the boiler; that is, the engine, separator or drying apparatus may be anywhere below with no effect upon the loop's action except the additional work imposed. This would, however, be a limiting condition when the riser column became so long that the pressure at its lower end is insufficient to lift the total weight of mixture into the horizontal. For instance, if the loop is working under five pounds difference, from fifteen pounds to ten pounds (see *Fig. 3*), and if the riser is so charged with water that the specific gravity is say ·1, then when the horizontal further reduces the pressure to say six pounds, there would be a total forcing pressure up the riser of four pounds, which would support a water column eight feet high or a column one-tenth as heavy eighty feet high. The horizontal in this case would stand about thirty feet above boiler water, hence the foot of riser can extend about fifty feet below boiler. Similar figures for eighty pounds boiler pressure, with seventy-five

pounds at engine and drop of ten pounds in horizontal would allow riser to run about 150 feet below boiler level. The above considers only a static column, but if we allow for the sweeping action of the current ascending the riser, the allowable distance of riser foot below boiler will be much increased.

Distance of Foot of Riser above Boiler.— Evidently the foot of riser can be elevated to any required extent, but there will be a height depending upon difference of pressure at

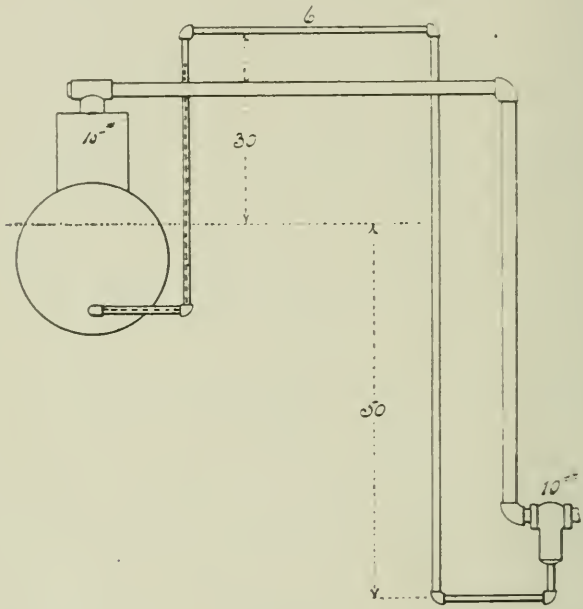


FIG. 3.

which the true functions of the loop may seem to become superfluous. Consider the case where the drain is just at a height above boiler water equal to the hydrostatic head due to the difference of pressure (see *Fig. 4*). Then, with no riser in the system, water collecting in the separator will run directly down a pipe, similar to a drop-leg, into the boiler. This water must collect in ordinary liquid state and exert gravity pressure before the column can move. The velocity of its exit depends wholly on the amount that has collected. Should the difference of pressure increase slightly, accumu-

lation is necessary to cause drainage. This is simply a gravity system. It has no current carrying the water swiftly from separator and over a hill to a point of safety on the top of a water column on the other side, which may rise and fall from time to time without affecting the flow from the point that is to be drained. A gravity system is a water pipe sufficiently high to overcome a difference of pressure. A steamloop may be called a gravity system from the boiler to the top of water column in drop-leg, but a

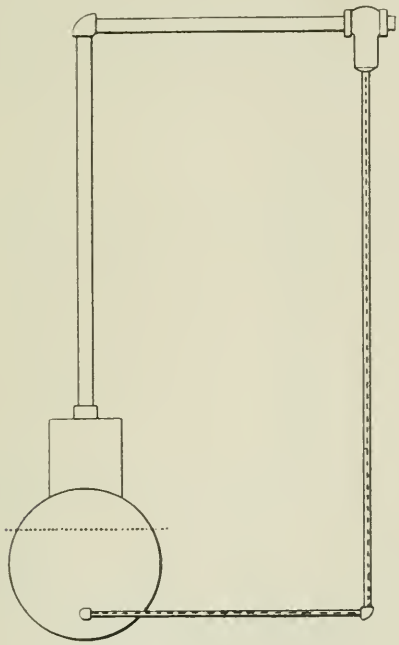


FIG. 4.

steamloop essentially is a device extending above a balancing column, with such functions as enable it to create a circulation that is not dependent upon gravity or the incoming water of condensation, but wholly upon the flow of steam from a higher to a lower pressure, and so arranging the mechanical device that this flow will carry water with it. Therefore, even though the source of condensation is far above the boiler, the principle of the loop is just as applicable to constantly and positively remove water as

though it were below and its virtues are just as essential. If the height above the boiler is far in excess of the head due to maximum difference of pressure, the loop may take the form of a straight pipe, the first section of which may be considered a riser, the second a horizontal and the last or lowest a drop-leg (see *Fig. 5*). Such a pipe would be a limiting case of steamloop, its shape distorted, but its functions retained. The true action occurring in such a pipe has heretofore been imperfectly understood. Indeed, it is

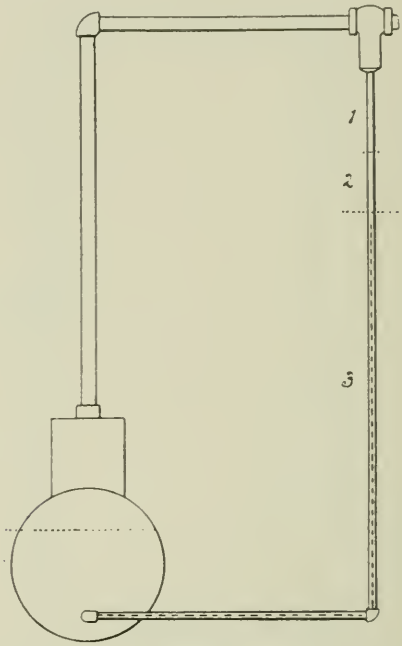


FIG. 5.

quite probable that no one has considered it deserving of especial consideration until the steamloop was devised and explained.

Distance.—It might not be unreasonable to suppose that the steamloop's application would be quickly limited by the distance of the separator from the boiler, and that the length would introduce complexity or uncertainty of action. Extreme length might impair its action, although even this is questionable, but at the greatest distances thus far met, of

800 to 1,000 feet, no adverse conditions have been encountered. Great distances cause proportional drop of pressure within the loop itself, requiring proper allowances to be made in height of drop-leg. The temperature of return is also affected, due to the cooling effect of long pipes, and can be largely controlled by proper covering. The drop of pressure mentioned above, due to the length of loop, occurs only when a horizontal is extremely long, hence is rarely met in practice. In extensive systems the horizontal is made only the functional length, turning into the drop-leg, which descends, and at a proper level can be led away through piping of any form to the boiler (see *Fig. 6*), it being evident that when the drop-leg has descended to the level of boiler water, all

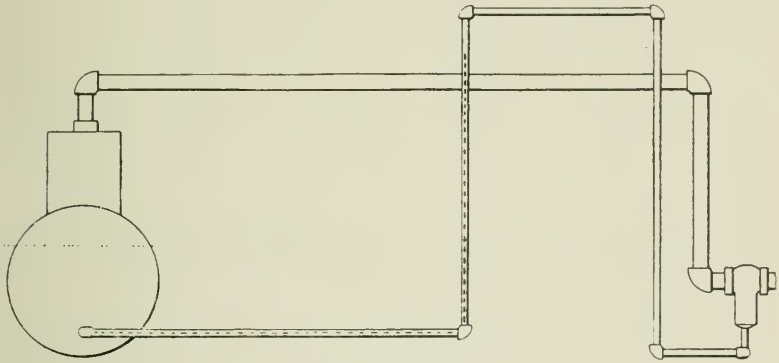


FIG. 6.

further connection to boiler, whether one foot or 1,000 feet, becomes merely an ordinary pipe through which water will seek its level as through a pipe connecting two barrels into one of which water is poured. Thus, distance will be noted to impose no practical limit on the loop's application, for it causes no change in the loop itself.

Quantity of Water Returned—This depends upon the amount of moisture entrained in the steam, the condensation in the pipe and the boiler primage. Usually there is little attempt to classify water appearing in a steam system according to the causes of its existence. Its presence is simply regretted until harm results, and then it may be less considerately mentioned. If water is only to be drained out,

as by drips, etc., when it accumulates in considerable volume, it matters little how it is formed, but when we come to handle it systematically, continuously, and with certainty, we must consider the source of the product on which we operate. *Water of entrainment* causes steam to be known as wet, and is usually constant in quantity. It may be separated from the steam in several ways, means for this being provided in the various forms of separators, and when so separated must be led away from the main steam current so continuously that it cannot again be picked up. *Water of condensation* is supposed to flow along the bottom or be swept along the sides of pipes, and is also usually constant in quantity. It requires no true separation, but must be led into a chamber of suitable size in such a manner as to readily leave the column of steam with which it is flowing. As most pipes afford opportunity for water to collect at certain points, and then rush on with the steam, the receiving chamber should have ample capacity. *Water of primage* is erratic. Its presence is accidental. We cannot estimate its probable quantity, or the nature of its passage through the pipe. It may be so received by the pipe as to cause excessive entrainment, as is probably the case when an engine labors, clicks and shows very wet exhaust. It may come over as liquid, and mingling with the water of condensation, cause an engine to slow down, pound and collapse, or spurt streams of liquid water from the exhaust. It may be constant or intermittent, and is always dangerous. It must be led away from the steam current, and received in a chamber whose capacity is considerably larger than that required for water of entrainment or condensation.

A separator must, therefore, provide ample facilities for separating the particles of entrained water from the steam and ample capacity for moderate primage. (Extreme primage is, of course, beyond control, and requires cure rather than care.) The loop must have capacity sufficient to continuously discharge the water collected from entrainment and condensation, and a maximum working effort, or single impulse, equal to taking in one liquid stream the contents of separator when filled up to a certain limit by sudden

primage. (If filled beyond this limit, we have a flood, whose control is not within the province of the loop or any other instrument, and must be left to Providence.)

This double service, for which the loop must be proportioned, involves the ratios existing between the volumes of the separator, riser and horizontal, for the horizontal must have a volume sufficient to take the contents of separator and drop-leg, and still have space left to be occupied by steam, whose condensation will maintain a continuous action while the water in the horizontal is draining through the drop-leg.

This action, while apparently intermittent, is not truly so. It is intermittent with reference to the extra charge of water carried, but the loop is simply exerting, in an emergency, its maximum ability, which, if constantly required, would not be inconsistent with its principle of continuity, although different proportions would then be desirable. Thus, the quantity of water to be handled becomes a limiting condition only when it is so great as to literally flood the system.

Devices for increasing capacity have been employed, such as cored risers, flattened risers, but experimentally they have not, as yet, produced such results as to warrant adoption.

When a loop is not sufficient to give the required capacity, it is not enlarged, but duplicated, and this process may be continued to any extent. When two or more loops are applied to one source, no difficulties are met in their operation, except some competition as to which will secure the business of returning the water. A little influence exerted, in the detail of pipe connections, enables them to form a trust, in which the spoils are equally divided with satisfaction to all concerned, even the public.

Another method, when primage is excessive, is to place a separator on the steam pipe near the boiler, with contents looped back directly, thus compelling the separator and loop at the end of the system to handle the water of condensation only. This method has been used with marked benefit (see *Fig.* 7).

Presence of Air.—To start the loop's action, the air must

be removed by blowing out with steam, hence it is proper to inquire whether air would not collect in the horizontal and gradually reduce the action and make it eventually become "air bound." There is certainly sufficient air in steam to produce this action, but in practice it does not. This may be attributed to the high velocity at which the loop current flows, carrying the air forcibly back to drop-leg where it enters the water and condensing steam, returning to the boiler. Only one instance is known where the loop has met difficulty of this nature, and that was due to boiler water containing much organic matter, the gases from which would collect in the loop. The remedy in such a special case is to apply a small stand pipe to the horizontal

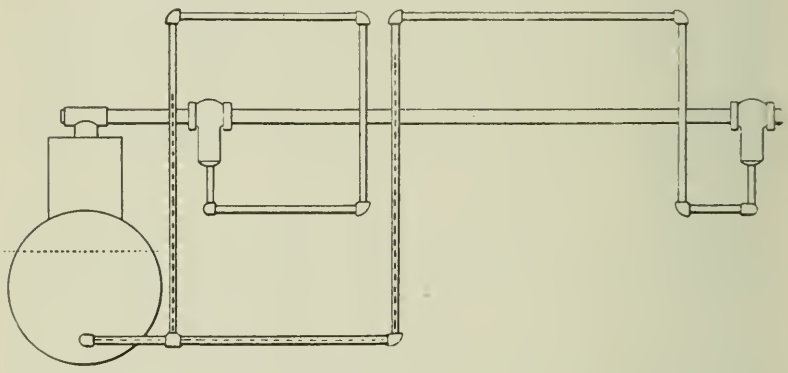


FIG. 7.

in which the air or gas can collect, cool, and, by difference of temperature, operate an air valve, allowing escape until steam rushes in and closes the valve.

To sum up the limitations, we find the loop action is practically independent of the distance that the source of supply is above or below boiler, and also independent of the length of return. It is not interrupted by the presence of air, and is capable of handling such quantities of water as usually exist in steam systems. It is practically limited by excessive differences of pressure and by abnormal quantities of water.

Constructive Features.—When a device is so simple as to consist of a run of one inch, or one and one-fourth-inch

pipe, it may seem unnecessary to endow it with so significant an attribute as constructive features, but there is a right and a wrong way to run even an inch pipe. When the mission is so special as that of the loop, there is only one right way and numerous wrong ways. To enter into this matter in detail would be too long for the present discourse, hence we will consider only a few points of especial interest and without extended explanation.

Practice has determined that one inch or one and one-fourth-inch pipe is most suitable for risers, while drop-legs generally take one and one-fourth inches to one and one-half inches, seldom two inches, and never larger. Horizontals commonly are two inches, but, as the volume is material, they may be four inches or even six inches if very short; with reference to them, however, no rule can be considered generally applicable, for the volume of the separator may figure as a large or small element, according to the necessity for handling primage, while the ratio of superficial area to volume is important in giving proper strength to the circulation and determining the economy with which it shall operate.

All horizontal portions of the loop should pitch downward with the current. It may be well to remark here that the terms "riser," "horizontal" and "drop-leg' do not necessarily imply that risers are always vertical, horizontals always horizontal, or that drop-legs follow a plumb line. A riser is the entire run of pipe from separator to highest point of the loop, and may have horizontal portions. The horizontal is the summit level of pipe in which condensation produces the loop's action, and though usually horizontal, is not necessarily so. The drop-leg is frequently inclined, and may have almost any form.

The riser should be provided with a stop valve and the drop-leg with stop, check and blow-off valves. The check must have approximately equal areas on both sides, or when shut it will be much out of balance and become a serious obstacle to the returning water. The return must be made with an independent connection, for if connected to feed pipe, the pulsations caused by pump would affect the drop-

leg, while if connected through blow-off, especially if it be in a mud drum, the loop may disturb the sediment.

The riser and drop-leg should invariably be covered with good non-conductor to prevent loss of heat, while the horizontal should be covered wholly or in part, according to its length and size, and the necessary condensation.

Combinations of Several Loops.—Thus far we have considered the loop as an isolated device, returning the water from one separator attached to one steam pipe. The application may, however, be extended throughout a large steam system; in fact, it is one of the important features that the entire drainage of a large system of steam pipes can be made with a system of loops forming a network of returns back to the boiler, affording ample opportunity to clear the system of water and with no chance for waste by escaping steam through faulty or open drips. It matters not whether the pipe be overhead or underground. Loops can be attached directly to the bottom of steam pipes at low spots and separators may be used at each steam outlet where engines, pumps, dryers or other apparatus operate. When the system thus extends, it is pertinent to examine to what extent the loops may be combined to simplifying piping. On first thought it may be proposed to simply run all the drains to one point, and there attach a loop of sufficient size, but the impropriety of this is at once apparent, since such loop would be liable to receive nothing but water and would be promptly flooded. Each loop is proportioned and erected with reference to specific difference of pressure and a given quantity of water, hence if the drainage of several separators into one loop is considered at all, these separators must be attached to pipes bearing such relation to each other that they will all be subject to equal differences of pressure. Consider a large and small engine side by side, the large engine having constant load while on the small one the load varies widely. If these separators be drained into one loop, there would be opportunity for a sudden drop of pressure near small engine, caused by sudden increase of load, bringing the contents of the large separator over to and possibly through the small engine. This could be

obviated by introduction of check valves, but they are undesirable, and the loop system is so capable of being made to work properly on its own intrinsic principles that it would seem to be bad engineering to create a set of conditions in which the loop needed auxiliary devices to counteract effects which should not be present. Similarly, when large quantities of water are received by one drain or separator, its presence might so overload the loop as to render it inoperative with respect to the several other connected sources. Therefore, one loop should never be connected to several sources of supply, except in rare cases where the different sources may be considered only as subdivision of one source; that is, when they are all subject to the same influ-

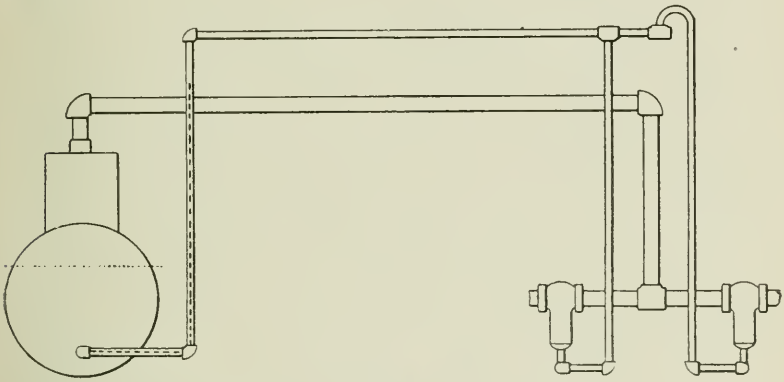


FIG. 8.

encing conditions. Each source of supply should therefore have its own riser. If, now, several risers from various sources enter one horizontal, we would afford opportunity for the loop's fundamental principles to be violated. The circulation must be uninterrupted and end at the point of lowest pressure. There cannot be more than one point of lowest pressure, hence with two or more risers connected into one horizontal, an accidental drop in pressure in any riser or pipe to which it is connected would short-circuit the loop from one riser to another (see *Fig. 8*). Therefore, each riser must have its own horizontal. We then consider whether several horizontals can enter one drop-leg. The balancing water column whose height is due to difference

of pressure must rise and fall with the variation of pressure. Hence, one loop may have a different height of balancing water column from another, even though they enter the same boiler. At the origin of one loop pressure may be increasing, while at another it is decreasing, calling for corresponding fall and rise of drop-leg columns, and if these loops were both attempting to utilize the same drop-leg we should have the anomalous condition that a column of water is required to rise and fall at the same time, and hence two or more horizontals should not enter one drop-leg. The numerous drop-legs in a given system do not, however, require independent connection to the boiler, for they may discharge into one common manifold or header near to or distant from the boiler. The loop's action is performed when the water has been deposited in the drop-leg; hence, the method of connection beyond that point does not involve the action of the loop. Even if loops could be combined and connected in various ways consistently with safety and reliability, it would not be generally expedient or convenient so to do, for though several loops may be more complex, they are less complicated than several combined into one with numerous shut-off valves, opportunities for leakage and interruption to service which may ensue when for any reason part of the loop system is shut down and the balance in operation. With individual loops the shutting down of part of steam plant simply cuts out single loops without effect upon the others.

Efficiency.—This is a feature of the loop on which it would be interesting to develop thermodynamic equations, and compare the same with experimental results, but the investigations on thermodynamic lines involve numerous assumptions on which the doctors will not agree, while experimentally we labor under the disadvantage of having no general case, each experiment requiring to be conducted on a special case, which may have but little bearing on others. By this it is not implied that the quantitative values of loop action are not or will not be determined mathematically and experimentally, but rather to say that such determinations are not of much import or interest in the

present discussion. A statement of general features surrounding the efficiency may, however, be interesting. The loop may, like an engine, operate idly, doing no useful work, because there is no water to return, in which case it would be infinitely wasteful, since the efficiency is the ratio of the cost of operation to the work done. The operative cost being practically constant in any given loop, its efficiency must depend wholly upon the amount of water returned and the maximum efficiency will correspond to the largest quantity that it is capable of handling. This limit, however, would seldom be reached in practice, for if constantly doing its maximum work the loop would be in danger of flooding each moment. Practically, therefore, the wide margin allowed for safety and handling unusual quantities of water compels the loop to usually operate far below its maximum capacity rendering it to that extent less efficient. This feature, however, indicates the inadvisability of making loops unnecessarily large. Since the loop puts water into the boiler against resistance, energy must be expended. This energy represents heat lost, and this loss is the cost of operating the loop. No exact determinations have been made of this loss, but it is obviously very small. This is indicated by the fact that the loop will work even when covered with non-conductor. That the energy required is very small may be deduced as follows:

A 100 horse-power engine using thirty pounds of water per hourly horse-power requires 3,000 pounds per hour. If ten per cent. or 300 pounds be returned to boiler per hour, and difference of pressure between separator and boiler is ten pounds, then about $\frac{1}{275}$ of one horse-power is required to do the work.

In the above it will be noted that we have assumed a very large amount of water to be returned, and have assumed a large difference of pressure against which to return it. Consequently the above figures are more than generous, and it is doubtful whether half this amount of power, or say $\frac{1}{500}$ of one horse-power, is used in the average case. As the loop is required to exert so small a power, it is evident that its efficiency, as measured by our ordinary ideas of economy,

might be extremely poor, and yet its efficiency for the purpose for which it is used very high; that is, while its absolute efficiency considered as a pump with which to get water into a boiler might be low, the small amount of energy needed to perform so valuable a service as continuous return, may make it relatively an article of high efficiency.

Another way of looking at this is as follows: A one-inch pipe may be presumed to lose by radiation ·1 of the heat which would be lost from a ten-inch pipe. Now, suppose a ten-inch pipe is running from a boiler to an engine, and the loss by condensation is being wasted through a drip, to say nothing of the steam also lost. Now, the loop will add one-tenth to the condensation but to compensate for this it returns to the boiler the original ten-tenths condensation in the pipe, plus the one-tenth condensation in itself, at a temperature (say) of 250° to 300°, which is evidently desirable as compared with wasting the condensation of the ten-inch pipe.

An important factor in its practical efficiency is the improbability of leakage existing, while other methods involve great opportunities in this direction.

There are other interesting developments with relation to efficiency which cannot be explicitly stated because of insufficient experiment. They may be indicated as follows: In any system which involves carrying from the boiler steam at a given temperature and returning a part of same to said boiler, there must be some loss of heat. The amount will depend on the differences of temperature to which the steam or resulting water is subjected and the time. All systems contemplating the collection of water in volume, handling it through pipes in volume and pumping it back in volume, contemplate or involve the use of apparatus having itself a temperature widely different from that of live steam from said boiler. They also contemplate the moving of a solid body of water which can only be done at a very low rate of speed. Hence, any return made on such system is essentially a wasteful one. The steamloop makes a return through apparatus which is small in mass and kept at a comparatively high temperature, while the current through it is

extremely rapid, bearing in this respect no relation to any other device. Both difference of temperature and time are so reduced as to give evidence of superior efficiency. In fact, it may be said that the steamloop cannot be reasonably compared with any other form of return that has yet been made, as it stands alone in its principle and utility.

This whole question of efficiency is, however, one of curiosity rather than importance, for, as previously stated, the whole matter is relative. The mechanical features of the loop system in removing the objectional water from pipes, through a continuous closed circuit back to boiler takes precedent over any questions of efficiency, especially considering the very small quantities of power and their heat equivalents involved. Just as an edge several inches wide may be sharp for the bow of a steamship and an edge ·01 of an inch broad dull for a razor, so may the expenditure of a few thousand heat units in a lightly loaded steamloop be economical for a loop when the same number of hundreds of units would be uneconomical for a compound condensing engine furnishing the same foot-pounds of work. Loops, therefore, are simply to be compared with each other, and in this field there is still ample room for further accumulation of data.

In practice, the data obtained from large numbers of loops in operation vary so widely on account of various conditions imposed, that it is probably impossible to obtain reliable information from which deductions can be made, except on special apparatus erected on a large scale for experimental purposes only. The useful work done by the loop cannot be measured solely by the amount of water returned to the boiler, for if this water is all condensation and primage, its removal produces less economic effect on an engine than if it were held in suspension in the steam. Thus it may be that the exertion of a small fraction of a horse-power by a loop may cause the steam which it dries to exert many times more power in its expansion in the engine cylinder. The loop to do this might be lightly loaded, so that its own efficiency becomes relatively poor, while near by there might be a loop, heavily charged with water of primage and con-

densation, whose efficiency is relatively high, yet whose economic effect upon an engine is of less value. Therefore, the thermodynamic efficiency of a given loop is not proportional to its value to the user, even though we make no account of its value as an assurance against accident by water.

Results.—The result of steamloop action may be briefly summed as follows:

(1) Saving the water of condensation, entrainment and primage.

(2) Saving the heat contained in said water.

(3) Saving the steam systems from water, thereby reducing liability to accident.

(4) Returning pure water to the boiler.

(5) Preserving uniform temperatures, thus obviating difficulties due to expansion and contraction.

(6) Prevention of direct loss which usually exists from open drains, drips, tanks, etc.

(7) Enabling engines to start promptly.

(8) Maintaining higher pressures at the end of long lines.

(9) Maintaining higher temperatures in jackets, dryers, etc.

(10) Increasing the efficiency when steam is used expansively.

All of the above are more or less evident from what has preceded, except the latter, and on this there is some honest difference of opinion. The earlier writers on thermodynamics make little mention of the effect of entrained moisture on the expansive properties of steam, but by common consent rather than any demonstration, they seem to agree that moisture produces an ill effect simply to the percentage amount of its presence. That is, five per cent. moisture will increase the water rate of an engine only five per cent. Experimental data on this point seem very meagre, the only recent work being that of Prof. James E. Denton, of Stevens Institute, on a comparatively small engine in which the result indicated was substantially as above. Prof. Denton, however, considers further experiment necessary to establish a con-

clusion. The opinion of other authorities on this question, including Dr. R. H. Thurston, of Cornell University, and Geo. H. Barrus, M.E., of Boston, agree that the presence of moisture in steam should, and doubtless does, cause an injurious effect in excess of its own percentage. Indications of this are observed in superheated steam where a given amount of heat expended in superheating produces more saving in the quantity used by the engine than the equivalent in added heat, and the same condition should extend to supersaturated steam. Definite knowledge of this is, however, yet to be obtained, but it seems to be the general concensus of opinion that moisture is detrimental to an extent about double its percentage ; that is, five per cent. moisture in steam, effects the efficiency of an engine about ten per cent. Further development and opportunity for experiment with the steamloop system will aid in determining this.

Other Applications.—Throughout this discourse the description has been confined almost wholly to the application of the loop to the one case where moisture is to be removed before steam passes to an engine or pump. It is thought best to keep this one case clearly in mind, for the loop thoroughly understood on this basis may be easily conceived to serve similar purpose in any other connection. Where live steam is used for drying purposes, the loop may be attached directly to the return, this maintaining a powerful circulation through the heating coils and ridding the system from the condensation which is the natural product of the heating or drying process. In this service, however, the loop has opened up a new feature, that of drying the steam before it enters such heaters, and it is found to yield very beneficial results, by keeping up temperatures and pressures (see *Fig. 9*). Similarly, steam kettles, jackets of steam-jacketed cylinders, and even steam-heating apparatus can be handled with ease and efficiency. Much apparatus of this nature, however, is throttled down to a degree that seriously interferes with loop application, and in ordinary steam heating the opportunity is exceptionally good for large air leakage, which would be deleterious. It is, there

fore, not easy to concisely state to just what purposes the loop may be practically applied, but it is safe to say that it is desirable on any live-steam pipe or any high-pressure or unthrottled dryer, heater or jacket.

The development of the loop system has not stopped with the simple applications here recorded, but has been carried into fields of wider application. Perhaps no device has appeared during late years on which more thought and careful consideration has been bestowed. Its possibilities have been explored and its limitations studied to such an extent that the whole evening would scarcely suffice to enumerate

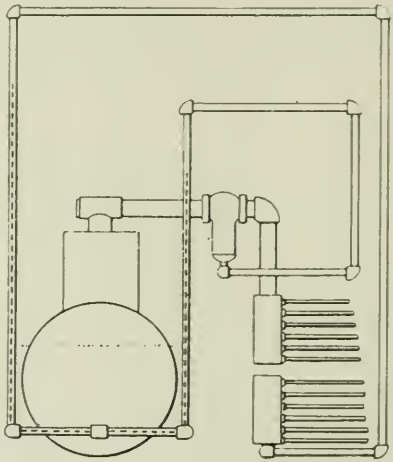


FIG. 9.

features of interest that have not been included in this lecture.

Thus, the steamloop becomes a device of much broader proportions than appears from first inspection of its operation or the rudimentary understanding of its principles. It may seem strange that its application has not before been developed, but that is doubtless due to want of clear comprehension of its somewhat peculiar functions and their utility, for those who are connected with steam engineering must in many ways and under various circumstances have had opportunity to observe the phenomena which concern

its action. We are, therefore, entitled to respect quite highly this useful combination, whose worth can never be accurately estimated, since its chief service is to prevent certain losses and accidents of variable character, and whose extent is the only measure of the loop's value.

THE PATH OF A PROJECTILE.

BY F. GILMAN, Lowell, Mass.

The object of the present article is to show how well the equation of a projectiles path, developed on the hypothesis that the resistance varies directly as the velocity, conforms to the experimental results of the Chief of Ordnance, U.S.A.

I shall also submit the equation to the same test when developed on the hypothesis that the resistance varies as the square of the velocity, although in this case the comparison will necessarily be restricted to experiments in which the angle of elevation was very small. As the equation of the trajectory deduced on the assumption of a resistance proportional to the velocity, is not generally given in treatises on mechanics, we will briefly show how it is derived.

Let the resistance be expressed by $c\,v$, in which v is the velocity, and c a constant that expresses the resistance for a unit of velocity. The origin of coördinates will be taken at the point from which the projectile is thrown, x being the horizontal and y the vertical axis.

Let t denote the time, and g the acceleration of gravity. Then, according to the fundamental equations of mechanics:

$$\frac{d^2x}{dt^2} = -c\frac{dx}{dt} \tag{1}$$

$$\frac{d^2y}{dt^2} = -g - c\frac{dy}{dt} \tag{2}$$

Let

$$b = \frac{dx}{dt}$$

and substitute this in (1).

It becomes

$$\frac{db}{dt} = -cb$$

$$dt = -\frac{db}{cb} \tag{3}$$

and integrating,

$$t = -\frac{1}{c} \log b + C$$

in which C is the constant of integration.

In order to determine its value, let v denote the initial velocity of the projectile, and α the initial value of the angle which its trajectory makes with the axis of x. Then, since the time is estimated from the beginning of the motion.

$$o = -\frac{1}{c} \log (V \cos \alpha) + C$$

$$C = \frac{1}{c} \log (V \cos \alpha)$$

whence,

$$t = \frac{1}{c} \log \left(\frac{V \cos \alpha}{b}\right) \tag{4}$$

Multiplying equation (3) by b, we have,

$$bdt = dx = -\frac{db}{c}$$

and integrating with due reference to the value of the constant,

$$x = \frac{V \cos \alpha - b}{c}$$

whence,

$$b = V \cos \alpha - cx$$

and substituting this value of b in the above expression for t, we obtain,

$$t = \frac{1}{c} \log \left(\frac{V \cos \alpha}{V \cos \alpha - cx}\right) \tag{5}$$

This equation gives the time required for the projectile to reach any point in its path whose horizontal distance

from the origin is equal to x. In order to integrate equation (2), substitute b for

$$\frac{dy}{dt}$$

and proceed exactly in the same manner as for equation (1). We find,

$$t = \frac{1}{c} \log \left(\frac{g + c\ V \sin \alpha}{g + cb} \right) \tag{6}$$

Equations (4) and (6) give the time required for the projectile to reach any point in its path.

Equating them and restoring the values of b:

$$\log \left(\frac{V \cos \alpha}{\frac{dx}{dt}} \right) = \log \left(\frac{g + c\ V \sin \alpha}{g + c \frac{dy}{dt}} \right)$$

Passing from logarithms to quantities, taking the reciprocals and multiplying through by dt,

$$\frac{dx}{V \cos \alpha} = \frac{gdt + cdy}{g + c\ V \sin \alpha}$$

Integrating, substituting for t its value from (5), and solving with respect to y,

$$y = \frac{g + c\ V \sin \alpha}{c\ V \cos \alpha} x - \frac{g}{c^2} \log \left(\frac{V \cos \alpha}{V \cos \alpha - cx} \right) \tag{7}$$

which is the equation of the trajectory.

An analysis of this equation shows that a perpendicular to the axis x at a distance from the origin equal to

$$\frac{V \cos \alpha}{c}$$

will be an asymptote to the curve.

Differentiating the equation, and finding the value of x from

$$\frac{dy}{dx} = o$$

we obtain

$$x = \frac{V \cos \alpha}{c} \left(\frac{c\ V \sin \alpha}{g + c\ V \sin \alpha} \right) = \frac{V^2 \sin \alpha \cos \alpha}{g + c\ V \sin \alpha}$$

which gives the horizontal distance from the origin at which the projectile attains its greatest elevation. This value of x substituted in equation (5) gives

$$t' = \frac{1}{c} \log \left(\frac{c\ V \sin \alpha + g}{g} \right)$$

which gives the time in which the projectile will reach its greatest height. The expression for this height is

$$y = \frac{1}{c} (V \sin \alpha - g t^1)$$

From equation (7) we deduce the following formula for the range

$$R = \frac{g\ V \cos \alpha\ t}{g + c\ V \sin \alpha}$$

The value of c depends on the initial velocity, the nature of the projectile, and the angle of elevation at which it is thrown. For each class of projectiles, and for each initial velocity, taken at intervals of from 50 to 100 feet per second, there will be a certain curve whose abscissas will represent the angles of elevation, and its ordinates the corresponding values of c. *Fig. 1* shows such a curve, which gives the values of c in the experiments made by the Chief of Ordnance on the firing of two guns, and recorded in his report for 1885, pp. 66, 495. One of the guns was a fifteen-inch Rodman smooth bore. The projectile was round iron solid shot, and its weight 455 pounds. The initial velocity was 1,678 f. s.

The other gun was a 3·2 inch breech-loading rifle. The projectile was a solid band experimental shell, and its weight thirteen pounds. The initial velocity was 1,602 f. s. The values of c, plotted from these two sets of experiments, gave two curves, which ran so nearly together, that it was thought best to combine them into one mean curve, providing that the computed results would agree with the experiments, as well as the experiments agree with themselves.

The following table gives a synopsis of the results:

15-INCH RODMAN GUN.

Angle of Elevation.	Value of c taken from Diagram, *Fig. 1.*	Range		Time of Flight	
		By Experiment.	By Formula.	By Experiment.	By Formula.
		feet.	*feet.*	*seconds.*	*seconds.*
2°	0·0673	5,300	5,230	4·0	3·5
5°	0·1112	8,857	8,810	8·1	7·9
10°	0·0890	13,696	13,636	13·9	14·9
15°	0·0748	16,651	17,319	19·1	21·5
20°	0·0660	19,285	20,043	23·8	27·7
23°	0·0622	21,243	21,268	26·4	31·2

3·2-INCH BREECH-LOADING RIFLE.

Angle of Elevation.	Value of c taken from Diagram, *Fig. 1.*	Range		Time of Flight	
		By Experiment.	By Formula.	By Experiment.	By Formula.
		feet.	*feet.*	*seconds.*	*seconds.*
2°	0·0673	4,755	4,797	4·0	3·3
4°	0·1148	7,093	7,096	6·7	6·2
6°	0·1065	9,109	9,215	9·0	9·0
8°	0·0974	10,907	11,066	11·5	11·7
10°	0·0890	12,450	12,770	13·7	14·3
12°	0·0818	14,472	14,354	15·7	16·9
14°	0·0770	15,810	15,658	17·9	19·4
16°	0·0725	17,070	16,890	20	21·9
18°	0·0690	18,291	17,944	22	24·3
20°	0·0660	19,437	18,870	24	26·6

The fourth and fifth of the Rodman experiments show the greatest discrepancies, amounting to about four per cent. of the range. It will be found, however, on examining the separate experiments of which these are the mean, that they show differences among themselves of from seven to eleven per cent. The initial velocity was measured only in the first few experiments, and it was assumed to be the same in all the others, as the weight and kind of powder was the same. But it is probable that this assumption is

not strictly correct and it would have been desirable to have had a measurement of the initial velocity at each experiment, as it seems likely that the differences in the ranges corresponding to the same angle of elevation are principally due to differences in the initial velocities. The c curve given in *Fig. 1* of accompanying plate, is peculiar in that it shows such a great variation in the value of c for angles of elevation between 2° and 4°.

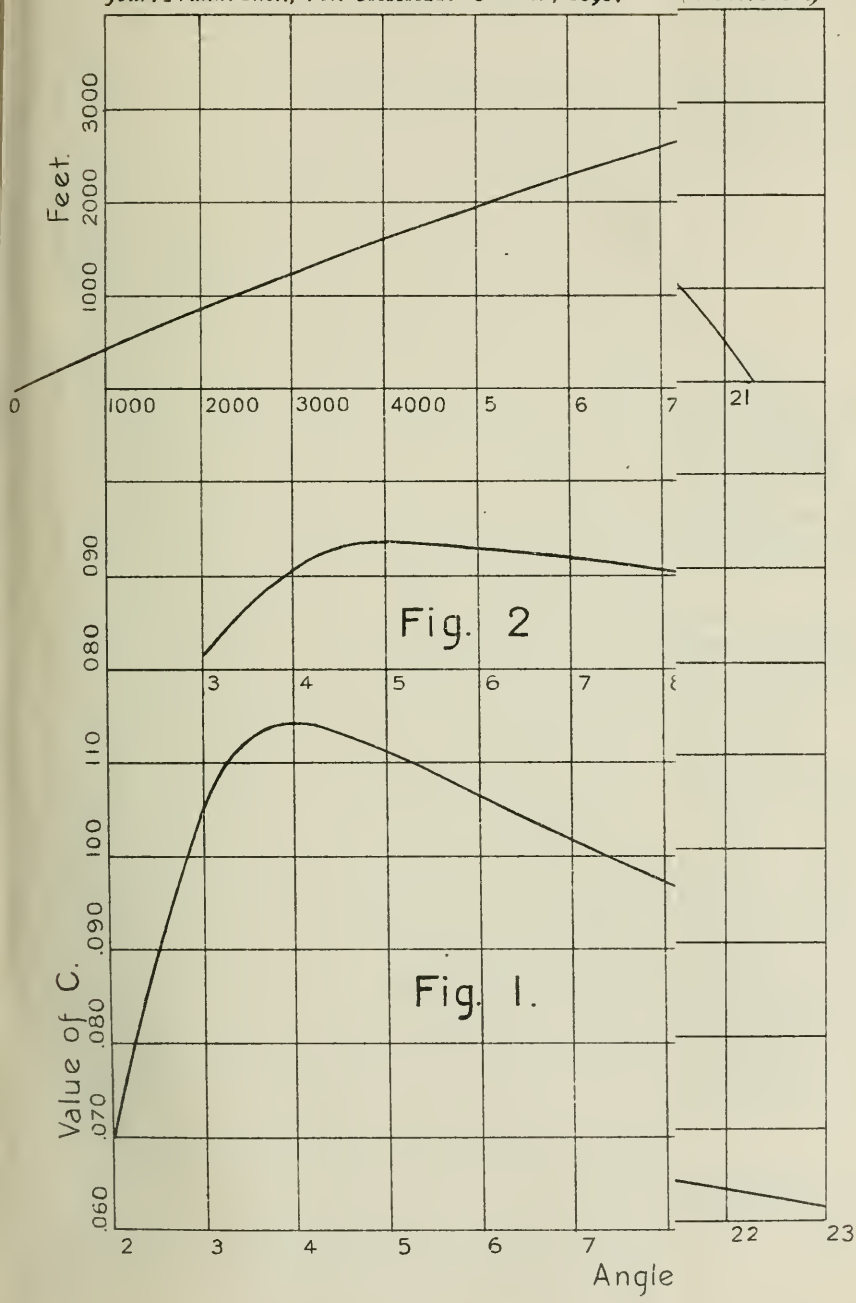
Beyond 5°, as the angle of elevation increases, the value of c gradually diminishes, and the curve is very regular.

The curve was constructed so as to give as correct values as possible for the ranges, and without regard to the times, which were left to come out as they would. It will be noticed that the computed times are smaller than the observed for angles of elevation of from 2° to 5°, that from 5° to 6° the observed and computed times are practically the same, while beyond 6° the excess of the computed over the observed values gradually increases with the angle of elevation.

If it were required to compute the time with greater exactness, let t' denote the corrected value, t the value obtained directly from formula (5), and denoting by n the angle of elevation (expressed as seconds), we will have for the Rodman gun, $t' = t - (\frac{n}{10})^2$ and for the 3·2-inch rifle, $t' = t - \frac{n}{10}$.

These formulas will apply when the angle of elevation exceeds 8°. *Fig. 2* shows the c curve for experiments made with the forty-two millimetre Hotchkiss mountain gun, and recorded in the Ordnance Report for 1885, p. 88. The initial velocity was about 1,300 f. s., and the weight of the projectile, one pound fifteen ounces.

Fig. 3 represents the path of a projectile as deduced from data of one of the Rodman gun experiments above recorded, the angle of elevation being 23°, and the value of c 0·0622. The values of the ordinates were calculated from equation (7) for every 500 feet of horizontal distance, and the results plotted, give the curve. It is unsymmetrical in form, and flatter on the ascending than on the descending side, as is known by observation to be the case, in the


Feet.
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2000
3000
4000
5
6
7
21
090
080
Fig. 2
3
4
5
6
7
110
100
.090
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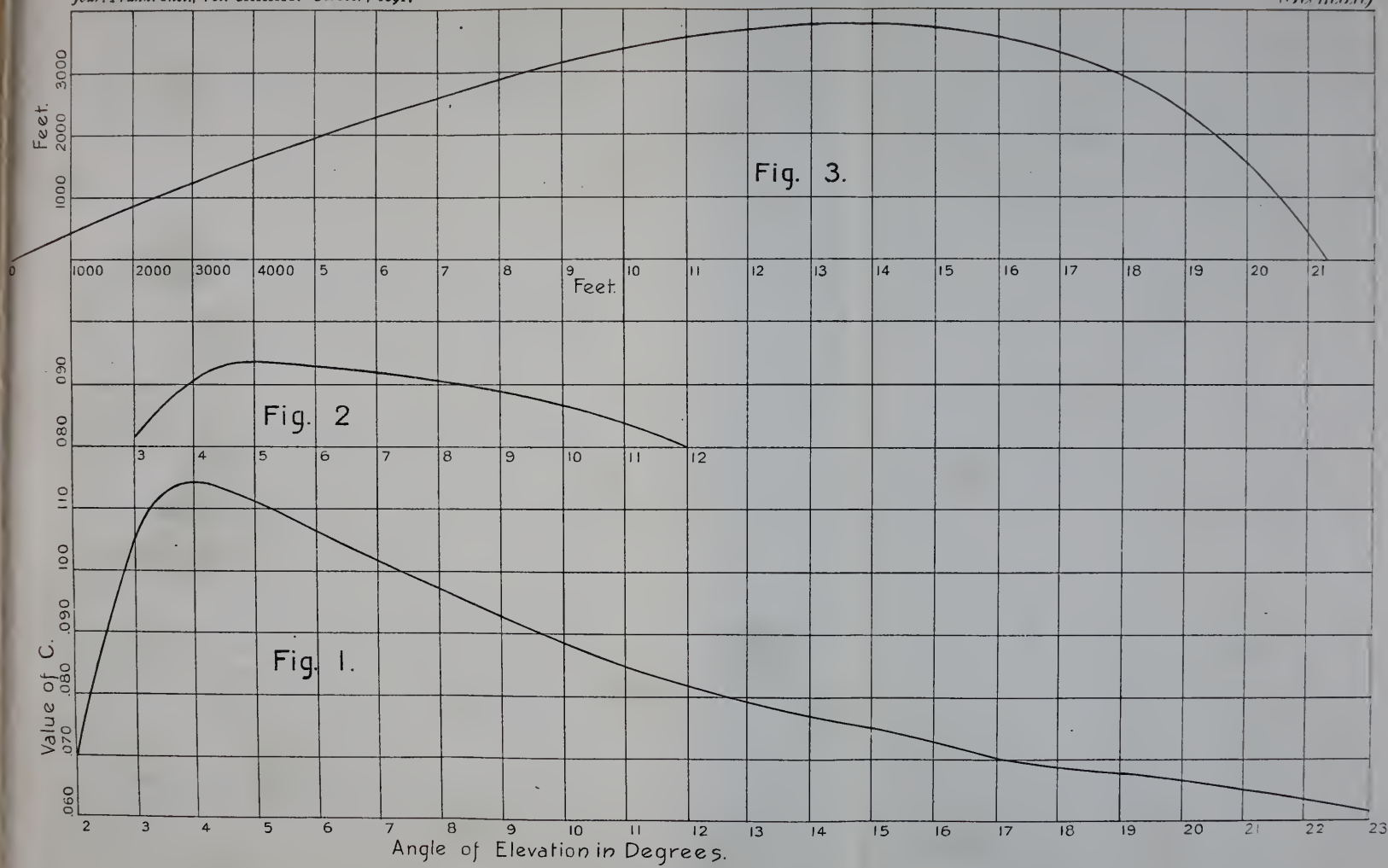
.070
.060
Value of C.
Fig. 1.
2
3
4
5
6
7
22
23
Angle


Feet.
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Feet.
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Fig. 3.
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Fig. 2
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070
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Value of C.
Fig. 1.
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Angle of Elevation in Degrees.

actual path of a projectile. The horizontal distance from the origin at which the projectile attains its greatest elevation is, in this example, about two-thirds of the range.

In order to show how well these ordnance experiments sustain the hypothesis of resistance proportional to the square of the velocity, we will take the equations that apply to this case, and which are generally given in treatises on mechanics.

$$t = \frac{1}{c\,V \cos a}\,(e^{cr} - 1)$$

$$8\,c^2\,h \cos^2 a\,r \tan a = e^{2cr} - 2\,cr - 1$$

In these equations t represents the time of flight, a the angle of elevation, v the initial velocity, r the range, h the height due to the initial velocity, and c the constant of resistance. Since these equations can be applied only to cases in which the angle of elevation is very small, we will select for comparison the first two of the Rodman gun experiments.

We find that the value of c, which is obtained by substituting for r the correct range, is in the first experiment 0·0000386, and in the second 0·0000810. The corresponding realness of the times are 3·5 seconds and 7·7 seconds.

We see then that for angles of elevation between 2° and 5° c is even more variable than was found to be the case on the hypothesis of a resistance proportional to the velocity, and as the constancy of the value of c (at least for small angles of elevation), would seem to be a good test of the accuracy of the hypothesis on which it is based, it follows that the assumption of a resistance proportional to the square of the velocity is no better sustained by these experiments, than was the assumption of resistance directly as the velocity. The values of c for the first two experiments with the 3·2 inch breech-loading rifle, are 0·0000486 and 0·0000855, and the corresponding values of the times 3·3 and 6·1.

It appears that the resistance of the air can hardly be expressed in terms of any single power of the velocity, but

I think it can be expressed quite accurately by the following formula:

$$R = a + bv + cv^2$$

in which R is the resistance, v the velocity, and a, b and c three constants to be determined by experiment. I have applied this formula to the experiments of Hutton on air resistance, and after determining the values of the constants by least squares, found that it satisfied those experiments within the limits of probable errors of observation. The range of the velocities was from 950 to 2,050 feet per second.

The greatest difference between the computed and experimental resistance was about three per cent., and the most of them were much smaller.

But, although this formula probably represents the law of resistance, yet to attempt to make it the basis of a mathematical deduction for finding the equation of a projectile's path would be a hopeless problem, from its complexity. It seems more practicable to find the elements of the trajectory by the first method shown above; especially since the results of that method are as accurate as those arrived at on the generally accepted hypothesis of resistance proportional to the square of the velocity.

The GALVESTON HARBOR PROBLEM.

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The importance of securing a deep water harbor on the west coast of the Gulf of Mexico in developing the commercial, industrial and agricultural resources of the United States, and especially of the Trans-Mississippi region, can hardly be over-estimated.

The many elements affecting the problem in its commercial, and to some extent in its political, relations, have been ably stated in the recent paper on "Southwestern Commerce and Gulf Harbor," by Senator W. P. Frye, who presents the subject from the standpoint of the statesman, but it is quite as important that the question should be considered from the standpoint of the engineer, as it is upon this phase that the success of the project must depend.

The desirability of such an outlet for the products of the 1,000,000 square miles of tributary territory does not admit of doubt. The practicability of securing it has led to several animated discussions in the engineering world as well as in Congress, and while definite and positive conclusions have been reached by individuals, the great majority of legislators regard the problem as a huge "experiment," and are willing to defer formulating an opinion until results are obtained.

In engineering, as in legal practice, precedents are invaluable and failures teach more than successes, as they often determine the limits within which a given method may be applied with success. It is the purpose of this argument to apply this test to the locality in question, considering it first, *per se*, in the light of its own history, and second by comparison with existing conditions and results elsewhere so far as they may be applicable.

The peculiar difficulties and great importance of this question have given zest to the discussion and have

attracted the highest grade of talent to its consideration, hence its history will be found bristling with interest even to the unprofessional reader.

When, in 1869, the writer was on duty as Engineer Officer of the Fifth Military District (Texas), it was often impossible for the Morgan Line steamers, built expressly for the Gulf trade, to cross the bar at Galveston and other ports of Texas. Passengers, cattle, baggage and freight were frequently lightered ashore at great risk of being dumped into the water, or drenched by the breakers on the bar, and to this day, at many of these ports, no improvement has been effected in this tedious, dangerous and expensive mode of effecting a landing. Then, the outer bar at Galveston was three miles from Fort Point and had a channel depth across it varying from twelve to twelve and one-half feet, and vessels frequently had to "lay to" outside the bar for days awaiting a favorable wind and tide before undertaking an entrance. Having passed this barrier and rounded Fort Point a contracted channel was entered, which constitutes the harbor proper. This channel lies between Galveston and Pelican Islands, and is separated from the outer roadstead by a recent formation known as the inner bar.

In the report of Lieut. Stanton, made in 1868, it is said: "The harbor proper, obstructed by this bar, is 6,000 yards long and only 250 yards wide, measured within the 12-feet curves, affording to ships of 12 feet draught very scant space for turning about." Again, in the report of the Board of Engineers of January 21, 1886, occurs this statement: "On the north side of the island in front of the city of Galveston depths of 35 feet are found in a narrow channel. This area of 270 acres forms Galveston Harbor." * * "The main entrance to the bay * * has a present width of 8,200 feet." The depth here, in the "gorge," is 40 feet. "The interior of the bay, aside from the main entrance, has depths which do not exceed 11 feet at mean low water."

As great stress has been laid upon the capacity of the harbor for deep draught vessels, these facts assume con-

siderable importance, in view of the plans proposed for improvement, and particularly with reference to the exaggerated impressions which prevail, due, doubtless to a superficial inspection of the charts of Galveston Bay, with its 451 square miles of area.

One of the recent official reports * on this subject, guardedly states: "The entire area, inside the outer bar, containing a least depth of 30 feet, is 460 acres, and there are 1,300 acres with a least depth of 24 feet, but these areas can scarcely with safety be referred to as Galveston Harbor without explanation, because over 500 acres of the 1,300, with a least depth of 24 feet, lie outside the gorge."

In fact, these 1,300 acres are embraced in the deep pocket, situated between the two sandy barriers separating the bay from the Gulf, and the outer and inner bars. They constitute virtually an outer, open roadstead, separated from the deep waters of the Gulf by the outer bar with its present maximum depth of 13 feet, at only one point on its crest and exposed to the full force of the Gulf storms—a more difficult trap to escape from than that of Apia and one possessing very few of the requirements of the harbor, even of refuge. The "White Squadron" on its recent visit to Galveston, was unable to enter this "harbor," not deeming it safe to venture nearer than about ten miles. These physical features must be given due weight in any comparison of sites for a terminal for the great Northwest. The problem is not local, but national, and the law of transportation which most affects the site, viz: that the water carriage should be continued as far inland and the land transit be made as short and easy as possible, should not be violated.

The inner bar is of comparatively recent formation. The "oldest inhabitant" remembers when it had no existence, and where there were 30 feet of water, in 1841, the depth had shoaled to 12 feet in 1853, due to material being carried in from the outer shore of Galveston Island.

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* *Ex. Doc. No. 56*, House of Rep., 51st Congress, 1st Session, dated Dec., 1889.

Up to September, 1854, the shoaling continued until the depth was but 10 feet, when a violent storm cut away its crest making a channel across it 15 feet deep. This depth remained very constant for eleven years, and in 1865, it was reported to be 14½ feet, but in 1867 the Coast Survey found only 9½ feet on the bar.*

The estimate submitted in 1868, for improving its depth so as to equal that of the outer bar, viz: 12 feet, was $1,300,000.

Such were the physical conditions before any material improvements were started, but the necessity for increasing the depth on the inner bar and the dilatory measures of the Government compelled the city of Galveston to undertake the work of constructing a pile-jetty over a mile in length in 1869, resulting in an increased depth of two feet.

This jetty was destroyed in part by the storms of 1875, aided by the ship worm (*Teredo navalis*). The first Government appropriation was made July 11, 1870, $25,000, followed by $20,000 the next year, and the engineer officer in charge was directed to submit a project for excavating and preserving a channel 80 feet wide and 12 feet deep across the inner bar "by the ordinary method of dredging."

After the lapse of over a year consumed in surveys and futile efforts to let the work by contract and in building dredges and scows, the officer in charge reported that "the work is not susceptible of permanent completion."† The year following he reported on July 20, 1872, that the dredge boat, steam tug and two scows, procured with the previous appropriations, "were not needed or worked during the year, due to the good effect produced by the jetty constructed by the City of Galveston," which caused a channel on the inner bar equal in depth to that on the outer bar. Under the circumstances the plant was held in readiness to work in case the jetty should be destroyed.‡

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* *Report Ch. of Eng'rs*, 1868, p. 509.

† *Report Ch. of Eng'rs*, 1871, p. 518.

‡ *Report Ch. of Eng'rs*, 1872, and was loaned to citizens to improve their docks.

The next appropriation of $31,000, June 10, 1872, was to be expended in surveys and maintaining the Galveston jetty. The year 1873 was consumed in surveys and further considerations, resulting in a project for securing an 18-foot channel over the outer bar by means of two jetties composed of "gabions filled with sand," at an estimated cost of $1,259,446.43. This project was submitted to the Board of Engineers at New York, who reported favorably in February, 1874, submitting a revised estimate, amounting to $1,759,401.85. The plan provided *two paralleled and submerged* jetties extending outward into the Gulf over *two and one-fourth miles apart*, and having a total length of 37,000 feet or over seven miles; an average distance of three and one-half miles from shore. For various reasons work on the jetty was not commenced until April 14, 1877, and from that date to January 1, 1880, the North jetty had been extended to sea nearly two miles. An examination made during that year revealed the fact that "the gabionade (North jetty) had essentially gone down below the original bottom, consequently it could not serve to direct or confine the currents."

Thus a decade passed in beginning the series of experiments to improve the outer bar. In the meantime, attention being thus diverted from the inner bar, it was left to the natural forces to maintain, and in September, 1875, a violent storm occurred which cut a new channel 12 feet deep through it at a point where the depth was only 7 feet, without reducing that of the old channel. This natural cut continued to improve, and by the following June had deepened to 17 feet. This gale of September, 1875, having destroyed the greater portion of the plant and material to the value of $50,000, several months were consumed in preparing to renew operations, by which time the appropriation was exhausted and that for the year 1876–77 being withheld, work was totally suspended until September, 1876, when a portion of it was released. Work on the inner bar was "completed" during that winter and then suspended until an equal depth on the outer bar should be obtained. The Fort Point gabionade having

been completed by June, 1877, it was observed that the deepening of the channel, started by the storm, still continued. The depths reported were in August, 1877, 16¾ feet; September, 1877, 18¼ feet; October, 1877, 19½ feet; June, 1878, 20¼ feet. This increased result may be attributed to the interception by the jetty, of the sand formerly carried into the channel, rather than to any scour produced by contraction of the channel.

As to the work on the outer bar, it was found, as already stated, that the gabions, which were 6 feet high had sunk from 4 to 7 feet, and that, "contrary to expectations, they did not become covered with sand, but remained standing in a trench entirely uncovered,"* although submerged. These and other peculiarities led the Board of Engineers to reconsider their plans of 1879, and to abandon the gabionade in favor of brush and stone jetties, which it was affirmed would "undoubtedly succeed." "The theory upon which the Board relies is that of contraction of the outlet to force the outflow into a narrow channel directed upon the bar to effect its removal, and lessen, if not entirely prevent, for a long time to come, its reformation." †

Herein is where a fatal mistake was made in attempting to apply a theory which was inapplicable to the existing conditions. To produce scour by contraction the jetties must be so close as to co-act upon each other, that the trenches produced by their reaction may meet, and so prevent the formation of a middle ground. To secure this result at South Pass the distance between the jetties was contracted from 1,000 to 600 feet, and there the current is rapid and nearly continuous towards the Gulf. At Galveston it is intermittent and the ebb is dependent on the free admission of the flood to the inner bay. To place two jetties so close as to co-act and to scour by their reaction on the currents, would virtually have shut out the force available for scour and would have so obstructed the outlet to this bay that in great storms the city would have been endangered. In this

* *Report Ch. of Eng'rs*, 1879, p. 911.

† *Report Ch. of Eng'rs*, 1880, p. 1205.

dilemma, this board located the two jetties with an interval of over *two miles* between them, expecting by this plan "to force the outflow into a narrow channel," and to obtain a depth of at least 25 feet with a mean tide of only 14 inches. No precedent for such a plan exists in the history of the world, and yet the statement is made that after exhausting the literature of the subject "the application of this principle offers every guaranty of success."* "The suggestions as to details of construction are tentative only," and the Board recommended the trial of several methods of construction, among them that the line of "the South jetty should incline more to the North, so as to contract the opening between the two at their outer ends, but still remaining more than two miles apart;" and add "it has always been assumed that the Galveston jetties are to be submerged, but to what depth can only be determined by results produced during the progress of their construction. Should an average height of 5 feet above the sand bottom prove sufficient, it seems probable they can be constructed for $40 per lineal foot." † The total estimate for a depth of 25 feet across the bar was $1,825,813.

Under this project, as modified, work on the submerged brush-mattress jetties was commenced in July, 1880, near Fort Point, under the supervision of a new officer in charge, and continued as rapidly as the exigencies of the case would permit. Work on the North jetty was discontinued during the experiments on the other. By June 30, 1882, 20,777 feet of mattress work (nearly four miles) had been laid on the bottom and 10,130 feet of the second course was in place. These were ballasted by stone brought from a distance.

At this date, it was reported that "the effect of this work was not such as one unfamiliar with the physical phenomena of our locality would be led to expect." (The survey gave a depth on the bar of 11½ feet.) During the succeeding year, 1883, it was stated by the civil engineering assist-

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* *Report Ch. of Eng'rs*, 1880, p. 1205.

† *Ibid.*, pp. 1229–30.

ant that "the gulfward movement of the bar, without a corresponding increase in depth upon its crest, would seem to indicate the importance of an early and rapid construction of the North jetty." Yet, although attention was thus early directed to its importance, up to this date nothing has been done on this part of the project, whereby the rapid advance of the bar might have been prevented and great expense saved.

The survey of 1884 "brings out prominently the fact of the advance of the outer bar gulfward, which effect was sought to be prevented by the rapid construction of the jetties." * * "Slight changes are noticed upon the bar, but no benefit to navigation has resulted yet."

Channels dredged on the bar are quickly filled up by the drift of sand from the North. "The North jetty is absolutely required, if it is expected to secure deep water."

This North jetty, as designed by the assistant civil engineer, and which was the most promising feature of that period, was a detached, concave structure rising above high water, and placed so as to protect the channel over the bar from the drifting sand and waves, which is the requirement of prime importance in this problem. It was to have been about three miles in length, but was never built, although approved and recommended by the officers in charge.

The appropriation bill having failed, the city of Galveston again came to the rescue with a gift of $100,000 to continue operations, and at this juncture Mr. Jas. B. Eads was induced to make a proposition to the Government to undertake the work on the basis of his offer made for the South Pass, of compensation only after results were obtained. To this end a bill was introduced into Congress, February, 1884,* authorizing him to undertake the securing of a 30-foot channel at a cost of $7,750,000, payable by instalments for each foot or more of gain in depth.

This bill was defeated by such plausible arguments as these, submitted through and by the Chief of Engineers: "Nine hundred and seventy-five thousand dollars has been

* Senate, No. 1652.

expended upon the construction of the South jetty, and the construction of the North jetty will cost $700,000. That the construction will give more than an additional two feet of depth in the channel connecting the harbor of Galveston with the Gulf is entirely certain." "The case can be plainly stated as follows: (The Government) with the expenditure of $700,000 and two seasons' work will obtain an increase of depth exceeding 2 feet and probably reaching 5 or 6 feet, while Mr. Eads and associates promise, after a period of 2 years and 8 months after the passage of the bill, to gain 2 feet in depth for an expenditure on the part of the Government of $2,000,000." "The North and South jetties placed according to the official plan can, by further extension into deep water and by the construction of auxiliary works, if needed, be made to develop all the depth of the channel which the nature of the locality will admit."

In view of these assurances, it may be well to look at the sequel as revealed by seven years of subsequent experience.

The bar has now barely 13 feet of water over its crest, which is nearly two miles further out in the Gulf than when the works were begun, and the conditions are by no means so favorable for success as they were in a natural state. The cost has been increased by requiring four additional miles of jetty work to be built at the outer end. Furthermore, the Government, having learned something from the hearings concerning the plans and methods of Capt. Eads, soon after re-convoked the Board of Engineers, who again modified the plans and estimates to include high-water stone jetties as being ultimately cheaper and more permanent than the mattress work, which was found to have subsided over sixty per cent., and which, if carried to the outer 30-foot curve, would cost $7,000,000, provided "the money be freely supplied." Their aggregate length would be nearly 54,000 feet or over *ten miles.*

The width between them was always a difficult question upon which Capt. Eads does not appear to have furnished information further than to say in reply to a member of Congress, who asked if they should be 12,000 feet apart:

"That is a matter I should take into serious study before I should determine what particular width and direction I should give but *I do not take it to be over 2,000 feet.*"

In this reply, he kept within the limits of similar maritime works to be found in the world, with one slight exception, where, by dredging, a depth of about 21 feet is maintained, yet the present official plan provides for a width of 7,000 feet or nearly *one and one-half miles*, which will prove an egregious blunder.

The impression which is being fostered that the present plans are those endorsed by Capt. Eads, and which gave promise of success is, therefore, erroneous, for although the details of the jetties are those proposed by him, their plan, form and position are far from according with its views.

A distinguished writer, in reviewing the results of this work to date, remarks that "after a series of careful experiments, a width of 7,000 feet was determined upon, and has so far proved entirely satisfactory."

As the history of these experiments shows that at no time was there more than a part of *one* jetty in existence, it is difficult to understand how a width of 7,000 feet between them could have proven satisfactory, as the result of careful experiments. No precedent for such construction is to be found in the annals of jetty building, since the world began. If Galveston be made the precedent, it will be an extravagant warning for future generations, as, instead of the deep and wide channel of a minimum navigable width of 2,000 feet at the surface and 600 feet at a depth of 30 feet, which a recent Board of Engineers have fixed upon as absolutely necessary for the contemplated port entrance, there will be merely the trenches bordering the flanks of the jetties and extending to a distance of a few hundred feet therefrom, produced by the lateral currents, and a middle ground with its prevailing depths of 12 to 13 feet between them. Jetties this far apart will be inert, and it would require two years to dredge a channel such as the above, even if the sea were to stand still and cease to supply sand to the bar for so long a period. Dredging has been tried and pronounced a failure, and no protection could be fur-

nished to a dredged channel, even if created, by jetties as now proposed, a mile and three-eighths apart, open to the storms and connected with the shore. It will be observed that the present width between jetties is a little more than half that originally considered necessary for the protection of the city.

Again, the fact that the volume of water passing out at each tide "exceeds by about 30,000 cubic feet a second the entire low-water discharge of the Mississippi River," is not reassuring as to the success of the work, since at the latter place the flow is practically constant, whereas at Galveston there must be an equal volume flowing *into* the bay. (The small land drainage being mainly consumed by evaporation does not sensibly affect the outflow.) There is, therefore, the very material difference that at Galveston the movements are virtually equal in volume, but opposite in direction, while they differ only slightly in velocity. Hence, the effects are due to the differentials between flood and ebb, while at the South Pass there is not this opposition of material forces, but a nearly constant outward discharge. If *two* jetties are built at Galveston sufficiently close to produce a scour by reaction between them, they will so reduce the influx of the tide as practically to destroy the only force available, and the problem becomes indeterminate. The only hope for Galveston is by a single jetty on the North flank of the bar, with possibly a short groin at Fort Point.

In the late animated discussion in Congress * concerning the special appropriation of $6,200,000 to complete the work under Government supervision and plans, it was stated that the people of Galveston accepted Mr. Eads' proposition to guarantee 30 feet of water across the bar for $7,500,000, and asked Congress not to give them any more money to be expended by Government engineers, in the hope that it would appropriate a lump sum, as it had done for the Mississippi, to be expended by Capt. Eads. "But Congress did not close with that proposition, and the engineers

* *Cong. Record*, March 30, 1890, p. 2874.

adopted nearly Eads' plan. They would not adopt it entirely, and whether we get deep water or not we shall at any rate have made an honest effort to do it, and if we fail, the failure will be such that its repetition will not be invited. For that reason, Mr. President, I think we ought to pass this bill."

This quotation is sufficient to show the animus of Congress in relation to these public works, of so great importance to the country. It is to remove the odium which has been placed upon this honorable body, for the failure of many of these works, on the plea of withholding appropriations. In this case at least the *onus* will be removed to the executive department having charge of the works, and it is risking nothing to say that unless the present plans are materially modified, this large sum will merely have benefited the workmen and others employed or interested in executing the project. The extension of the South jetty has intercepted the littoral drift moving southward, building a shoal in the site of the old channel and causing a rapid progression of the bar seaward, which alone has added to the cost of the work more than the price of the jetty without increasing materially the depth of the outer bar.

The last report, made by the late civil assistant engineer, states "that upon the crest of the outer bar there has been a pretty general shoaling of from one-fourth to one-half a foot. The depth in the jetty channel, however, still remains at 13¼ feet, but the bar has advanced very perceptibly gulfward.

* * * "The shoal immediately North of the jetty has continued its gulfward advances. * * * The indications are that the probable effect of the further building of the South jetty will be the obliteration of the jetty channel itself. * * *

"The gulfward advance of the bar is not an unexpected result of the extension of the jetty, and I think we may expect a continuation of this advance until the equilibrium has been restored, or the supply of sand exhausted. * * *

"The sand has accumulated on the North side of the

jetty and some has passed over the crest and settled next to the base. This is another indication of the loss of force in the littoral current at that point, and also shows from which direction the sand is moving that has caused the shoaling."

The foregoing report, stating the facts so strongly, was only produced by order of the House of Representatives, and the sequel of its publication was an order to discharge its author from further service on Government works, after about eighteen years of intelligent and faithful service at this harbor.

The problem is not, however, hopeless; the North jetty should be built at once, but of such form and in such position as to control the prevailing natural elements which maintain the bar.

It is said that time and money will remove mountains, and while the aphorism is true of mountains, *in situ*, it cannot be applied to those in motion where the incessant forces of nature are continually constructing a path whereby they may traverse a breach in the coast. The remedy is not to be found in twin jetties, for such physical conditions as exist at Galveston.

Thus, after more than twenty years of experiments, frequent changes of commanding officers, several modifications of plans, the expenditure of $2,273,111.66 to June 30, 1890, and more than a quadrupled estimate of cost to complete, it may be said that the injuries caused by the works are greater than the benefits, and that the difficulties in the way of securing a deep water channel over the outer bar have been greatly increased rather than diminished, while it is proposed to apply $6,200,000 to a continuation of these experiments on a plan which must prove fatal. Such is believed to be a frank, though greatly abridged, statement of the problem of securing deep water at Galveston, as it exists to-day.

NEW CONSTRUCTIONS OF THE FORCE OF INERTIA OF CONNECTING RODS AND COUPLERS, AND CONSTRUCTIONS OF THE PRESSURES ON THEIR PINS.

By J. F. Klein, D.E.
Professor of Mechanical Engineering, Lehigh University.

[*Concluded from p. 206.*]

G.

We will now take up the general case of the quadric chain *ABCD*, *Fig. 8*. Here both cranks (or levers) *AB*, *DC*, have variable angular velocities. Let *AO* equal the acceleration of pin *A* in direction and intensity. It is required to find the acceleration of pin *D* for the given position and motion of the mechanism. For this case we will at once give both construction and proof.*

The velocity $\overline{Av} = \overline{AH}$ is found like the velocity $\overline{CV}$ in *Fig. 3*. On $\overline{AB}$ as a diameter we describe a circle. This cuts at *c* the perpendicular *Of* dropped on crank *AB* from the end *O* of the given acceleration *AO*. Then will $Ac = AH = Av$ be the velocity of pin *A*, because *Af* is the normal component of the acceleration, and the equation,

$$\overline{Af} = \frac{v^2}{R} = \frac{\overline{Ac}^2}{\overline{AB}}$$

is satisfied by the construction just given. (When point *f* falls beyond *B* outside of *AB*, then this construction fails

* *Fig. 8* is, in the main, like *Fig. 78a*, *Plate LII*, in Dr. Burmester's *Lehrbuch der Kinematik*. The construction and proof given above differ somewhat from that given there, but both are suggested by Dr. Burmester's treatment of the subject. The reader will find many interesting special cases in this masterly, German, work, and a wealth of constructions. But the method of finding the acceleration of the slide given in *Figs. 1*, *2* and *3* of the present article was not used there. A series of lines, in principle like the broken lines *WVB'TSw* of *Fig. 3*, and *DHJTSd* of *Fig. 8* was used there instead. This series is much simpler than any former method, but fails at the dead centre and gives poor *T* intersections when crank is near that centre.

and we must lay off $Af' = Af$ beyond A, and on Bf' as a diameter construct a circle; this will cut the tangent to the path of A at v and Av will be the desired velocity, for this construction also satisfies the equation.)

To find the velocity of point D, we draw HI parallel to AD, and because P is the instantaneous centre of link AD and

$$\frac{AH}{DI} = \frac{AP}{DP} = \frac{\text{velocity of pin } A}{\text{velocity of pin } D}$$

the lengths DI will measure the velocity of D. As each of

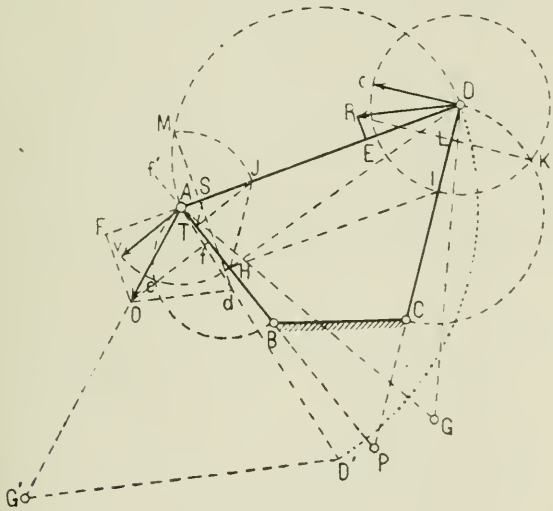

FIG. 8.

the instantaneous radii PA, PD makes the same angle (90°) with the direction of the velocity of the point to which it is drawn, they may be taken as the representatives of the velocities of the points A and D. Since velocities may be combined and resolved like forces, we may regard APD as a triangle of velocities, and either of its sides as the resultant of the other two. Thus PD may be regarded as the resultant of PA and AD. That is, the velocity of point D may be considered as the resultant of the velocity of point A about P and of the velocity of point D about A as a centre (the

angular velocity about A being then equal to that of A around P).*

Since AH represents the velocity of A and $HJ = DI$, the velocity of pin D, the sides of the triangle AHJ can replace the sides of APD as the representatives of the velocities. The length AJ thus represents on our scale the aforesaid velocity of point D of the rod when turning about its point A.

Let G represent the centre of acceleration of the link or coupler AD. The acceleration of A is proportional to the radius AG and that of D to the radius DG, and as these accelerations make constant angles with the radii, the radii themselves may be taken to represent the accelerations. As accelerations are compounded like forces or velocities, we see that the acceleration represented by the side GD of the triangle AGD is compounded of the accelerations represented by the sides AG and AD. In other words, the acceleration of the point D is compounded of the given acceleration AO of the point A and the acceleration possessed by D by virtue of the rotation of link AD about A (with an angular velocity equal to that which it has about G, which in turn is the same as the link's angular velocity about P).

The acceleration of D can be conceived as determined either by the rotation of CD about C, or by the compounding of the acceleration of point A with that caused by the rotation of link AD about A. In constructing the acceleration of point D, it will be easier not to confine oneself wholly to either of these determinations, but to find one component by each of these methods. For example: In the case before us, we find the radial component DL along DC and also the resultant radial component DE $(= FA + AS)$ along DA and erect the perpendiculars LR and ER at their extremities. As each of these perpendiculars necessarily passes through the end R of the total acceleration of D, their intersection will determine R and consequently the desired value DR.

* This can also be regarded as an example of the resolution of a rotation about an axis P into an equivalent rotation about another parallel axis A *plus* a translation that is itself equal to the absolute, circular motion of axis A.

The radial component of the total acceleration of D due to the rotation of CD about C is

$$DL = \frac{\overline{DI}^2}{\overline{CD}}$$

which can now be computed, or it can be constructed by drawing two circles, one from the centre D with radius DI, the other on CD as a diameter, and joining their intersections by a straight line, which will cut CD in the required point L.

To find that component of the total acceleration of D which lies along link DA we must remember that the motion of D is the resultant of the motion of A and the rotation of link DA about A with an angular motion equal to that with which DA rotates about instantaneous centre P. The component of the total acceleration of A which lies along DA is evidently AF and that which is due to the rotation of DA about A is AS and is found in the same manner as DL. We found above the velocity of D about A to be AJ. To get AS we draw two circles, one on AD as a diameter and another with AJ as a radius, and join their intersections; the connecting line will cut AD in the desired point S. This satisfies the condition $\overline{AS} = \overline{AJ}^2 \div \overline{AD}$.

There is another way of finding S when P is accessible. It is to draw BS parallel to PJ. Then we have

$$\overline{AS} : \overline{AJ} = \overline{AH} : \overline{AP} \quad \text{or} \quad \overline{AS} = \overline{AJ}\,\frac{\overline{AH}}{\overline{AP}} = \overline{AJ}\,\frac{\overline{AJ}}{\overline{AD}} = \frac{\overline{AJ}^2}{\overline{AD}}$$

There is still another way of finding S, one that is generally available, and that is to join D and H and draw through J a parallel JT to DH, and from T a parallel TS to CD. To prove this we have

$$\overline{AJ} \times \overline{AT} = \overline{AS} \times \overline{AH} \quad \text{also} \quad \overline{AJ} \times \overline{AH} = \overline{AT} \times \overline{AD}$$

multiplying these equations and cancelling we get

$$\overline{AS} = \overline{AJ}^2 \div \overline{AD}$$

We now have the component acceleration FS ($= FA + AS$) which acts along the link AD. Make $DE = FS$ and at

E erect a perpendicular *ER* to *AD*. This will be one locus of the end *R* of the desired acceleration of *D*. The perpendicular *LR* to *CD* has already been stated to be a locus and the intersection of the two loci will then completely determine *DR* as the acceleration of the point *D*.

If the direction of *DR* had been known, the problem would have been greatly simplified, for it would only have been necessary to draw through *O* a line *Od* parallel to the given direction *DR* and the intercept *Od* between *O* and the chord *MSd* would have given at once the intensity of the acceleration of *D*. This construction is directly applicable to the slider crank, greatly simplifying that particular case.

The construction given above for the quadric chain is applicable to a still more general case, namely, to a case in which the points *A* and *D* of link *AD* do not move in arcs of circles, but in any curves φ and λ whose centres of curvature are known. These centres may be put in place of the fixed centres *B* and *C* used above and then *BA* and *CD* will act as cranks of a quadric chain for two successive instants and the whole construction will be like that already given.

H.

We will now apply this general construction of the acceleration of the second pin *D*, when that of the first pin *A* is given, to the special cases represented by *Figs.* 7, 3 and 1.

In the quadric chain there is a particular case that often arises in practice, that in which the crank *AB* rotates with uniform velocity. As the crank radius itself can then represent completely both velocity and acceleration of pin *A*, the general construction is simplified, for it is not necessary to find point *H* (*Fig.* 8). But this can be reduced to the still more simple method of *Fig.* 7. As this is at the same time a symmetrical construction, it can be easily remembered. The proof is as follows:

The triangle *BAJ* is equal to the triangle *DHI*, and their homologous lines are equal and parallel. Then $VU = ED = FS$. By the general method the two normals *LR* and *UR* determine at once the acceleration *DR* of the pin *D* when the acceleration of crank-pin *A* is represented in direc

tion and intensity by crank radius AB. Now we have the proportion $DI : JN = QI : QN = QC : QB = CD : BJ$, hence

$$\overline{IN} = \frac{\overline{BJ} \times \overline{DI}}{\overline{CD}} = \frac{\overline{DI}^2}{\overline{CD}} = \overline{DL}.$$

This makes $BN = IL$, and since by construction $\overline{IU} = \overline{SJ} = BO$, we have the quadrilateral $BNrO$ equal to the quad-

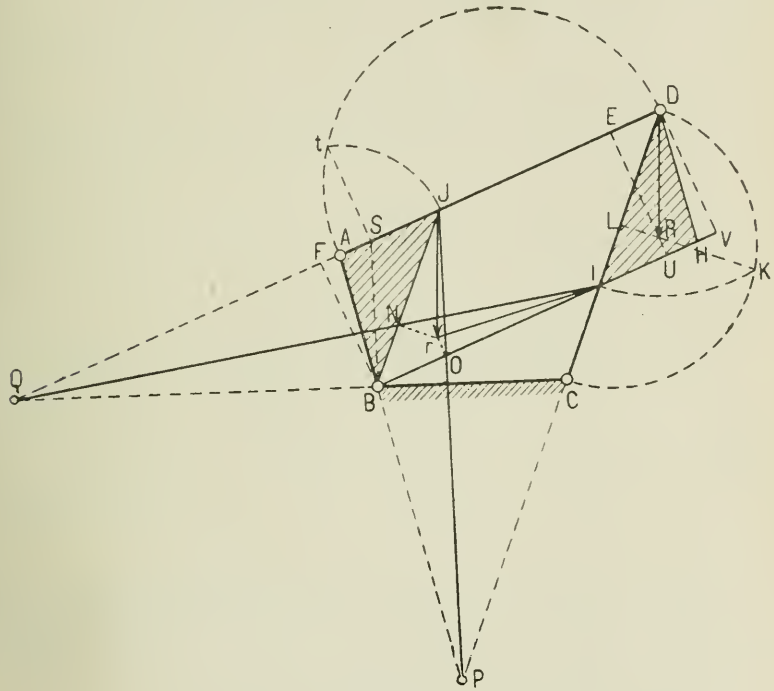

FIG. 9.

rilateral $ILRU$. As N and O are easily found, we can readily determine the length Jr, which is equal and parallel to DR, the required acceleration of the point D. This simplified and symmetrical construction has already been given with *Fig. 7*.

When the quadric chain $ABCD$ *Fig. 8* reduces to the slider-crank $LCWM$ of *Fig. 3*, the sides BC and CD of *Fig. 8* become parallel to each other, infinitely long and perpendicular to the stroke WN of *Fig. 3*. We construct the

revolved crank-pin velocity CV (*Fig. 3*) exactly in the same manner as AH of *Fig. 8*. Now through V draw VB' (*Fig. 3*) perpendicular to the stroke, for this is equivalent to drawing HJ parallel to CD in *Fig. 8*. The point S (*Fig. 3*) is found exactly as in *Fig. 8* (*i. e.*, a circle is described from C with CB' as a radius, and a second circle on the rod as a diameter) and chord tSv is then drawn. A second method of finding S is given by the series of lines $WVB'TS$ where $B'T$ is parallel to WV and TS is parallel to VB'. The method is evidently like that of the lines $DHJTS$ of *Fig. 8*. The acceleration of the slide W (*Fig. 3*) is now much more easily found than that of point D (*Fig. 8*), because the direction of W is given in its stroke, while that of D was unknown. To get the acceleration of slide W, we simply prolong the chord tSv till it cuts the line Ow, drawn through the end O of the crank-pin acceleration CO and parallel to the stroke. This is evidently in accord with the construction given for the case when the direction of acceleration of D (*Fig. 8*) is given.

Had the projection O' of O (*Fig. 3*) fallen on centre L of crank, we would have point V at L and the crank CL would have represented the revolved velocity of crank-pin and its special determination would have been unnecessary. In this case also we would have drawn LB in *Fig. 3* perpendicular to the stroke and taken CB instead of CB' as a radius of one of the circles for finding chord tSv.

In *Figs. 1* and *2* the velocity and acceleration are both constant, and are represented by the crank CO. A line through O parallel to acceleration of slide W, and terminating on chord tSv gives the desired acceleration Ow.

We have thus far supposed the acceleration of one pin of the rod or coupler completely known, and constructed the acceleration of the other pin. This enables us to find the acceleration of every point of a moving system like the coupler of the quadric chain, or the connecting rod of the slider-crank mechanism. For if the acceleration of two points of a plane system moving in its own plane are known, we can find the centre of acceleration of the moving system, and then the acceleration of any point of the system will be directly proportional to its instantaneous radius

from that centre, and the angle which its direction makes with this radius will be the same as that made by the other points with their respective radii. When the centre of acceleration of a system is known, and the direction and intensity of the acceleration of one point of its system is also given, then the accelerations of every other point can be easily and completely determined.

Our next step will be to establish simple methods of finding the centre of acceleration* and then apply these or their equivalents to the constructions already given. *Figs. 10, 11* and *12* are taken directly from Dr. Burmester's *Kinematik*, already referred to, and the demonstrations connected with these figures are likewise taken from this German work.

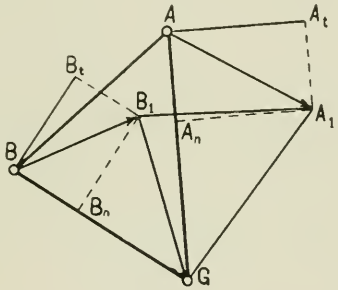

FIG. 10.

Suppose first that a plane, rigid, system S rotates about a fixed centre G (or one that is stationary for two successive instants), with a variable velocity. Then because the points A, B, . . . of this system have similar motions about G, the triangles GAA_1, GBB_1, . . . are similar, the sides AA_1, BB_1, . . . representing the acceleration of the points A, B, . . . consequently the triangle GA_1B_1 is similar to GAB. If we join the ends A_1, B_1, . . . of the accelerations by straight lines, and call the system which these form S_1, we can also say that *systems* S_1 and S *are similar, and the centre* G *is a point common*

* *Weisbach-Herrmann's Machinery of Transmission*, Introduction § 15–21, inclusive, give methods of finding this centre, of which that given in § 21 is the most convenient. But still simpler methods are available as the determinations in *Figs. 1, 2* and *3* have shown.

to both. Another way of putting it would be to say, that the *ends* of the accelerations together form an *image* that is similar to the original system, and that the centre G contains a pair of corresponding points.

It is evident that in this case the acceleration of one point being known we can easily find that of every other point.

If we suppose each of the accelerations AA_1, BB_1, . . . to be resolved into its normal and tangential components, AA_n, AA_t, . . . ; BB_n, BB_t . . . ; then will the system GA_nB_n, GA_tB_t be similar to the rotating system GAB, and the centre G will contain a pair of their corresponding points.

A more general case is where a plane system S has any arbitrary motion in its own plane. Let the distances AA_1, BB_1, CC_1, *Fig. 11*, represent the accelerations of the points of this system. Their ends will form a system $A_1B_1C_1$; that is, similar to the original system S or ABC. To prove this, we will reduce it to the preceding case, by giving to the system as a whole a motion just equal and opposite to that possessed by one of its points, say A; that is, the velocity and acceleration of this additional motion will be just equal and opposite to the velocity and acceleration of point A. This will cause the point A of the system to be at rest for two successive instants, and system S will turn about this fixed point A during these two intervals. Combine the additional and equal accelerations AA_1', BB_1', CC_1' with AA_1, BB_1, CC_1, respectively, by means of the parallelogram of accelerations. For point A the resultant will be zero, for point B it will be BB_1'' and for point C it will be CC_1''. Now we know from the preceding case because of this resultant rotation about A, that triangle $AB_1''C_1''$ will be similar to ABC. But because B_1B_1'' is equal and parallel to BB_1', and this in turn to AA_1, we have $AA_1B_1B_1''$ a parallelogram, and, therefore, A_1B_1 equal and parallel to AB_1''. In the same way we can show that $AA_1C_1C_1''$ is also a parallelogram, and, therefore, A_1C_1 equal and parallel to AC_1''. This will make triangle $A_1B_1C_1$ equal to triangle $AB_1''C_1''$, and as the latter is similar to ABC we also have $A_1B_1C_1$ similar to ABC, which was to

be proved. We can now enunciate the following proposition:

The ends of the accelerations of the points of a plane system having con-plane motion constitute a plane system (or image) that is similar to the first or moving system.

If we know the accelerations AA_1, BB_1 (*Fig. 11*), of two points A, B, of the moving system, the condition of the whole system with respect to acceleration is known. For we can get the acceleration belonging to any point C whatever, by constructing on A_1B_1 as a base a triangle $A_1B_1C_1$ that is similar to ABC. Moreover, two similar systems have only one common point that contains a pair of corresponding points. This common point is G, and is called the centre of acceleration. We will now proceed to prove the proposition italicized below.

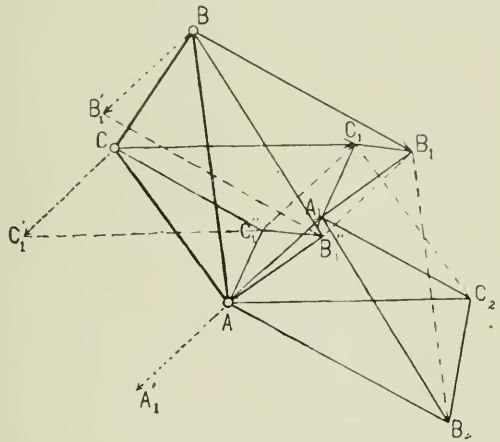

FIG. 11.

If, in *Fig. 11*, we draw AB_2 equal and parallel to BB_1, and AC_2 equal and parallel to CC_1, we shall have triangle $A_1B_2C_2$ similar to triangle ABC. To establish this we start with what was proved above, namely, that triangles $AB_1''C_1''$ and $A_1B_1C_1$ are equal to each other, have their sides parallel, and are similar to ABC. Then we must show that triangles ACC_1'' and ABB_1'' are similar. This is so because they have an angle CAC_1'' of the one equal to the angle BAB_1'' of the other, and $AC : AC_1'' = AB : AB_1''$. The next step is

to show that triangle $A_1C_1C_2 = ACC_1''$, and triangle $A_1B_1B_2 = ABB_1''$, and hence because the triangles in the last members of the equations are similar, those in the first members $A_1C_1C_2$ and $A_1B_1B_2$ are also similar. That $A_1C_1C_2 = ACC_1''$ is true, because the two sides, A_1C_1 and C_1C_2 of the one are respectively equal and parallel to the two AC_1'' and AC of the other, and the angles included by these sides are equal. In like manner it may be shown that $A_1B_1B_2 = ABB_1''$. We may, therefore, conclude that $A_1B_1B_2$ and $A_1C_1C_2$ are similar triangles. The next step is to prove triangle $A_1B_2C_2$ similar to $A_1B_1C_1$. Because the triangles $A_1B_1B_2$ and $A_1C_1C_2$ are similar, we have $A_1B_1 : A_1C_1 = A_1B_2 : A_1C_2$, and angle $B_1A_1B_2 =$ angle $C_1A_1C_2$. Taking from these equal angles the common angle $B_1A_1C_2$, we have angle $B_1A_1C_1 =$ angle $B_2A_1C_2$, and hence triangles $A_1B_2C_2$ and $A_1B_1C_1$ are similar. This makes triangle $A_1B_2C_2$ also similar to triangle ABC.

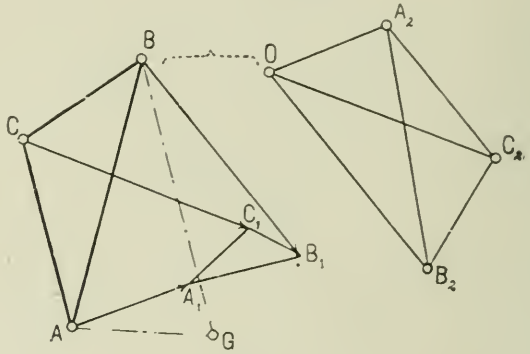

FIG. 12.

Now let us draw from any point O (*Fig. 12*) as a pole, the vectors OA_2, OB_2, OC_2, respectively equal to, similarly directed and parallel to, the accelerations AA_1, BB_1, CC_1 of the points A, B, C, of a plane system S, then will the points $A_2B_2C_2$ constitute a plane system S_2, which is similar to the original one S. Hence the proposition:

If from any assumed point as a pole we draw vectors parallel to, similarly directed and equal to, the accelerations of the points of any plane system having con-plane motion, the ends of these vectors will form a plane system (or image) which is similar to the moving plane system.

Finally, by constructing in *Fig. 12* the triangle ABG similar to the triangle A_2B_2O, we get in G, the desired centre of acceleration. It will not always be necessary to find this centre G in order to find the accelerations of all the points of the system, for it may often happen that the pole O may be assumed as to give the desired result more quickly and conveniently. *Figs. 1, 2* and *3* are good illustrations of this.

To apply this to our series of figures we will begin with the quadric chain, *Fig. 8*, and seek the centre of acceleration, G, of the moving system or link, AD. Here we know two accelerations, AO of pin A and DR of pin D. Take the end of the acceleration of A for the assumed pole, and draw from it Od, parallel, similarly directed and equal to DR. Then Ad may be regarded as a similar and reduced image of the coupler AD. We may take any row of points on AD, and a corresponding row on its image Ad, and the vector drawn to any point on Ad will be the acceleration in direction and intensity (but of course not in location) of the corresponding point on AD. Points on Ad corresponding to those assumed on AD can easily be found by drawing lines from AD parallel to the line connecting Dd. This last construction holds of course only so long as the points are on the centre line AD. When points are off this centre line we join them with each other and the pins A and D, the lines thus drawn forming with the link AD a closed figure. Then on Ad we construct an image similar to this figure. The vectors drawn to the points of this image will be the accelerations in direction and intensity of the corresponding points of the figure on AD.

The centre of accelerations G can be easily found from the directions given above. We have only to construct a triangle $G'AD'$ similar to oAd, but with side AD' equal to the link AD. For this purpose prolong Ad till $AD' = AD$, then draw through D' a line $D'G'$ parallel to dO till it cuts AO prolonged in G'. Now about A as a centre, revolve the triangle $AG'D'$ till AD' coincides with link AD the vertex G' will then move to G, and this latter point will be the desired centre of acceleration. It is evident that the ray

makes GA the angle GAO with the acceleration AO of A, and as this is the same at every point, we see that in this case the image deviates in position from its original an amount equal to the angle between the acceleration of any point and its instantaneous radius of acceleration.

In *Figs. 3, 2* and *1* there is no need of finding the centre of acceleration. In each of these O is the pole and Cw the image of the centre line CW of the rod. In *Fig. 3* the triangle $Cwgh$ is the image that is similar to the triangular

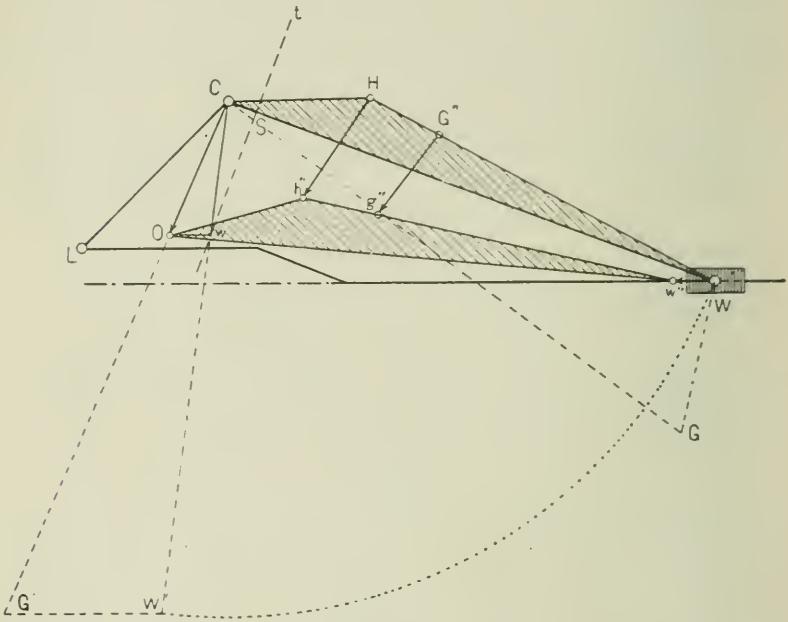

FIG. 13.

figure $CWGH$ on the rod. The vectors Og, Oh to the points g, h of the image give exactly the accelerations of the corresponding points G and H of the rod. The vectors give exactly the direction of the acceleration, because in each case the image makes with the figure, exactly the angle of acceleration. If for any reason the centre of acceleration of the rod is desired in any of these figures (say *Fig. 3*), it can be very easily found by prolonging Cw (*Fig. 13*) till it is equal to the rod $CW' = CW$, then through this point W'

draw a horizontal till it intersects (say at G') the crank prolonged in *Figs. 1* and *2*, or till it intersects the line CO in *Fig. 3* or *Fig. 13*. Then revolve this triangle $CW'G'$ about C till CW' coincides with its equal, the rod CW. The position G which this vertex G' then occupies will be the centre of acceleration desired.

That the ends of the accelerations form an image that is similar to the figure $CHG''W$ is also illustrated by the shaded area $Oh''g''w''$ shown in *Fig. 13*.

PROCEEDINGS
OF THE
CHEMICAL SECTION
OF THE
FRANKLIN INSTITUTE.

[*Proceedings of the stated meeting, held Tuesday, September 15, 1891.*]

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, September 15, 1891.

Dr. W. H. WAHL, President, in the chair.

Thirteen members and two visitors were present.

Mr. Pemberton nominated Mr. W. N. Allen, No. 2 Chestnut Street, Philadelphia, for membership in the Section. Owing to the absence of a majority of the committee on admissions, action upon the nomination was deferred.

Mr. Pemberton reported that Mr. Henry Bower and himself were present at the meeting of the Committee of the American Chemical Society, held during the past summer, in Washington, for the purpose of considering the establishment of a national chemical organization. He reported progress, and the committee was continued.

A number of bills, presented by the Actuary of the Institute, were considered by the Section, and the President was instructed to approve them for payment.

A paper by Mr. Cabell Whitehead, of the Mint Bureau in Washington, on "The Use of Cadmium in Assaying Gold Bullion," was read by the Secretary in the absence of the author. Dr. Tuttle commented upon the paper and discussed the most important advantages of the proposed method.

Mr. Waldron Shapleigh, of the Welsbach Incandescent Gas Light Company, of Gloucester, N. J., exhibited a series of specimens of salts of the rare earths. The collection was unique and of great interest and value. No such complete collection of these rare bodies was ever exhibited before a scientific body in this country. Mr. Shapleigh discussed the sources of the

minerals from which the salts were obtained, and also the methods of purification used.

The exhibition was highly appreciated by the members present.

The President of the Section tendered thanks to the exhibitor for the rare opportunity he had afforded the members of the Section. (Appended is a list of the preparations exhibited.)

Adjourned. WM. C. DAY, *Secretary.*

Mr. Waldron Shapleigh exhibited the following specimens of salts of the rare earths:

Praseodymium, neodymium and lanthanum oxides, sulphates, nitrates, chlorides, carbonates, oxalates, acetates and double salts with the alkaline metals.

Cerium oxide, oxalate, chloride, nitrate, and the double nitrate of the cerous and ceric oxides with ammonium.

Yttrium and erbium nitrates, oxides and oxalates.

Zirconium oxide, nitrate, sulphate and some double salts.

Yttrium and erbium (not separated) oxides and nitrates obtained from gadolinite, cerite, monazite, fergusonite and samarskite. Thorium and vanadium salts.

Also large specimens of the following minerals from which these salts were obtained: samarskite, zircon crystals and monazite sand from North Carolina, monazite sand from Brazil, gadolinite from Texas and allanite from Virginia.

Mr. Shapleigh said the collection was of interest, as it is the first time the salts of praseodymium and neodymium have been shown, and probably separated in this country. Some of the salts have not been heretofore prepared.

The separation of these elements is long and tedious; the specimens shown having undergone nearly 400 fractional crystallizations, and having been in state of constant preparation since early in 1888. Tons of cerite and monazite sand have been used, and tons of the salts of cerium and lanthanum obtained, but the yield of praseodymium oxide has been only a few kilos. The percentage of neodymium is much higher.

Dr. Carl Auer von Welsbach, in 1885, was the first to separate didymium into these elements, and together with Prof. Bunsen, to determine their atomic weights; that of Pr 143·6 and of Nd 140·8. The oxides are M_2O_3 and probably M_4O_7.

With one exception, the salts of praseodymium exhibited were of a pale green, and of neodymium pink or amethystine color.

Zirconium, lanthanum and cerium should no longer be classed among rare earths, as hundreds of tons of ores from which they are obtained have been located in North Carolina, and there seems no end to the deposits of monazite sand, one of the richest ores, and containing most of the rare earths. In Brazil it does not have to be mined, as it is in the form of river sand. In North Carolina it is found in washing for gold.

Should the arts, trades or manufactures create a demand for these so-called rare earths, nature could readily supply it from these two localities.

Thorium and yttrium minerals are not so easy to obtain; they have, however, recently been found in quantity in North Carolina and Texas.

Working on a commercial scale, he finds the yield of lanthanum from cerite nearly one per cent. higher than stated in the analyses published.

CHESTNUT-WOOD TANNIN.

By Prof. Henry Trimble.

[*Read at the stated meeting of the Chemical Section, held June 16, 1891.*]

The *Castanea Vesca* of Linnaeus or *C. Sativa* of Miller, variety *Americana*, is a large tree of rapid growth, found in many parts of the United States, especially in the eastern section from Maine to Delaware and on mountains as far south as northern Alabama.

An extract of the wood and bark has been prepared in this country and France for a number of years. This extract is especially useful in tanning where it corrects the reddish color of hemlock, and in dyeing where it gives a dead black with salts of iron. It must not be confounded with the extract of chestnut oak, *Quercus Prinus*, Linn., which is also largely manufactured in this country, and, no doubt, the manufacturers are not very particular to keep the two separate.

Most of the literature on the subject of chestnut tannin refers to that from the horse chestnut, *Æsculus Hippocastanum.*

In order to leave no room for doubt about the origin of the tannin described in this paper, the chips, free from bark, were collected from a large tree about forty years old, cut in the month of August.

A summary of the constituents of the wood, as found by a proximate analysis, may be of interest before commencing a description of the tannin:

	Per Cent.
Crystalline wax, melting at 50° C., soluble in hot 95 per cent. and in absolute acohol,	1·03
Gallic acid,	·05
Resin,	·28

	Per Cent.
Tannin, extracted by absolute alcohol,	3·42
Mucilage,	1·15
Dextrin,	1·89
Sugar,	·96
Tannin, extracted by water,	1·92
Pectin and albuminoids,	1·46
Extractive, dissolved by dilute acid,	2·95
Ash,	7·08
Moisture,	7·05
Cellulose and lignin,	70·76
	100·00

It is not certain that the gallic acid pre-existed in the wood, because it may have been formed during the drying of the chips, since the analysis was not made for some time after they were cut and ground.

A special determination of tannin on a separate portion of the wood by gelatin and alum and by permanganate and hide powder gave, respectively, 7·86 and 7·85 per cent.

The tannin used in the following experiments was prepared by percolating two and one-half kilos of the finely powdered wood with a commercial ether, which consisted of about seventy-four parts ether, twenty-six parts alcohol and a small quantity of water. The ether was recovered from the percolate by distillation and the residue dissolved in cold water. The filtered aqueous solution was precipitated in three portions by lead oxy-acetate, the precipitates decomposed by hydrogen sulphide, the latter removed by distillation under reduced pressure, and the solution after cooling agitated with ether, which extracted gallic acid from each of the three fractions. The tannin solution from the middle fraction was warmed to remove ether and then saturated with common salt. An abundant separation of tannin took place, which was collected, washed with a saturated solution of salt, and dried over sulphuric acid in a vacuum.

The dry residue was dissolved in ether-alcohol, filtered and rapidly evaporated to dryness under diminished pressure, which left the tannin in a porous, light-red mass. This was used for some of the qualitative tests, but for many of the reactions the tannin was further purified by

again precipitating in three fractions with lead oxy-acetate, the lead removed by hydrogen sulphide, the latter removed by distillation under reduced pressure, until the liquid had reached a small bulk, when it was agitated with ether, which removed gallic acid from each of the three fractions. The aqueous solution was then distilled to dryness under reduced pressure, the residue in each case dissolved in ether-alcohol, filtered and rapidly distilled under the same circumstances to dryness, which left the tannin in a nearly white porous mass completely soluble in cold water.

In physical and chemical properties this chestnut-wood tannin so closely resembled gallotannic acid that the following comparative statement is given, to show both the character and resemblance at once:

Reagent.	*Chestnut-wood Tannin.*	*Gallotannic Acid.*
Ferrous salts,	No change,	No change.
Ferric chloride and Ammonium hydrate,	Blue-black ppt., Purple ppt.,	Blue-black ppt. Purple ppt.
Tartar emetic and Ammonium chloride,	Slight clouding, Pale ppt.,	Slight clouding. Pale ppt.
Copper sulphate and Ammonium hydrate,	No ppt., Light-brown ppt.,	No ppt. Light-brown ppt.
Bromine water,	No ppt.,	No ppt.
Calcium hydrate,	White ppt. turning light blue,	White ppt., turning light blue.
Ammonium molybdate,	Yellow color,	Yellow color.
Sodium sulphide,	No change,	No change.
Conc. sulphuric acid,	Light yellow,	Light yellow.
Sulphuric acid (1 to 9),	No deposit,	No deposit.
Lead nitrate,	White ppt.,	White ppt.
Cobalt acetate,	Flesh-colored ppt.,	Flesh-colored ppt.
Manganese acetate,	White ppt.,	White ppt.
Uranium acetate,	Crimson color, turning dark red,	Crimson color, turning dark red.
Ammonium picrate,	No ppt.,	No ppt.
Potassium bichromate,	Brown ppt.,	Brown ppt.
Ferric acetate,	Blue-black color and ppt.,	Blue-black color and ppt.
Alkaloids,	White ppt.,	White ppt.
Gelatin,	White ppt.,	White ppt.
Lead acetate,	Light ppt.,	Light ppt.

One per cent. solutions of the tannins were used as recommended by Procter,* and all the reagents were applied in solution except sodium sulphide. These reactions do not all agree with those given by Procter, but he used a solution of commercial extract of chestnut which may have consisted in part or entirely of chestnut oak, or the difference may be due to the non-tannin constituents of the extract.

The chestnut-wood tannin was found to decompose, when heated to 200° C., into pyrogallic and metagallic acids, an abundant crop of crystals being obtained of the former. Each of the three fractions was estimated for sugar and the first found to contain 10·48, the second 7·98 and the third 6·18 per cent. of glucose, which, no doubt, had existed as a glucoside.

The second fraction was dried at 120° C. and submitted to elementary analysis as follows:

(1) ·1179 grams of substance gave ·2211 CO_2 and ·0486 H_2O.
(2) ·0843 grams of substance gave ·1575 CO_2 and ·0363 H_2O.

	(1)	(2)
C,	51·15	50·95
H,	4·58	4·79
O,	44·27	44·26
	100 00	100 00

On calculating for the presence of 7·98 per cent. glucose and deducting the difference from (1), we get:

	Found.	*Calculated for* $C_{14}H_{10}O_9$
C,	52 11	52·17
H,	4 40	3·10
O,	43·49	44·73
	100·00	100·00

It will be noticed that the percentage of hydrogen is greater than that in digallic acid, but in view of the fact that it was dried at 120° C. instead of 140° C., as recommended by Löwe,† and that it agrees so closely with gallo-

* *Text-Book of Tanning*, p. 112.

† *Zeitschrift für Anal. Chemie*, **11**, 378.

tannic acid in all its reactions, we cannot but conclude that it is gallotannic acid.

An acetyl derivative was prepared which in many respects resembled pentacetyl tannin, but the figures proving it could not be obtained in time for this paper.

PROCEEDINGS

OF THE

ELECTRICAL SECTION

OF THE

FRANKLIN INSTITUTE.

[*Proceedings of the stated meeting, held Tuesday, September 8, 1891.*]

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, Sept. 8, 1891.

Prof. EDWIN J. HOUSTON, President, in the chair.

Present, twenty members and visitors.

The minutes of the meeting of June 2d were read and approved.

The treasurer presented bills for printing and clerical work, which were ordered paid when approved.

Six nominations to membership were referred to the committee on admissions.

Prof. Edwin J. Houston read a paper on "The Artificial Production of Rain." There was much discussion on this subject, and also on the queries from the Question-box regarding the comparative intensity of the magnetic north and south poles of the earth, and the results obtainable in using Edelmann's electrometer as described in Ayrton's *Practical Electricity*.

The meeting then adjourned.

L. F. RONDINELLA, *Secretary.*

ARTIFICIAL RAIN-MAKING.

By Prof. Edwin J. Houston.

[*Read before the Electrical Section of the Franklin Institute, Sept. 8, 1891.*]

Whenever a large mass of air is cooled below the temperature of its dew point, the moisture it can no longer hold as invisible vapor, becomes visible. If the reduction of temperature be but slight, the vapor appears as fog, mist or cloud; if the reduction be considerable, as rain or snow.

There has been no little attention given lately to the question as to whether or not rain can be caused to fall at pleasure on any given section of the earth—rain machines, or artificial rain producers, consisting essentially of devices whereby explosions of nitro-glycerine, or other similar substances, are obtained at fairly considerably elevations in mid-air, have been tried in different forms. As to the success of these attempts at the artificial production of rain, the testimony appears to be uncertain or contradictory.

The idea of rain-making by mid-air explosions, is probably based on the rains that are generally believed to attend or follow great battles, Fourth of July celebrations of the Chinese character, and volcanic eruptions. Passing by the evidences produced by either the warlike or the peaceful burning of gunpowder, which at best are but vague, it may be remarked that volcanic eruptions may produce very heavy rainfalls, not only because the force of the eruption and the intense heat cause upward currents in the air, but also because of the vast quantities of vapor of water that escape from most volcanoes during their eruptions.

There is a fascination in witnessing man's struggle with the forces of nature; a struggle, be it understood, not made to oppose such forces, but rather to direct them. The former effort would be foolish, the latter must meet with success, if properly directed.

Do the scientific facts, as far as known to meteorology,

give any encouragement for the continuance of the efforts of the would-be rain-makers? Let us inquire:

It is now generally agreed that the lowering of temperature necessary for the production of rain may be obtained in the following ways:

(1) By the intermingling of masses of warm and cold air.

(2) By the carrying of warm, moist air into a cold place.

In any case the cause of the rain is, briefly, the cooling of the air until it is unable to retain all the moisture it formerly held as invisible vapor, and deposits the excess in a visible form as rain.

The quantity of the rainfall will, therefore, depend both on the amount of moisture present in the air, and on the extent of reduction of temperature produced.

The first method, viz: The lowering of temperature by the intermingling of masses of warm and cold air, can never produce any very considerable rainfall, since, though the warm air is cooled by its mixture with cold air, and the tendency is, therefore, to cause the mixed air to become relatively moister, yet, at the same time the cold air is made warmer, and therefore, relatively drier. Drizzling rains might be produced in this manner, but scarcely ever heavy rainfalls, unless both the cold and the warm air contain large quantities of moisture.

There remains, therefore, but the second way of lowering the temperature of the air, viz: by the carrying of the warm air into a colder place. This can be accomplished in three different ways:

(1) By a change of latitude, or by a warm, moist air blowing into a colder latitude. In general, the equatorial currents blowing toward the poles are the chief rain producers.

(2) By a change in altitude, effected by an ascending current, due to a heated area. Here the lowering of the temperature is due not only to the cold of elevation, but also to that produced by the expansion of the air under lower pressure.

(3) By a change in altitude, due to a mountain range

opposing the progress of a wind, and thereby necessitating its gradually creeping up the sides of the mountain.

In any of these ways heavy rains may be produced and, in point of fact, they are probably the only ways in which heavy rains are generally produced.

Applying the preceding principles to the case of the modern rain machine, let us inquire as to the probabilities of its successful operation. The simultaneous, or the successive explosion of large quantities of any high explosive, in the upper regions of the atmosphere, must produce, in general, a rapid and more or less thorough mixing or stirring of the surrounding air.

The sudden expansion of the air both by the heat liberated by the explosion and by the gases evolved during the explosion, is attended by a rush outward, followed by a rush of air inwards, towards the explosion centre. The direction of this latter rush is generally radially inward. In addition to these inward motions, the heat generated may tend to produce a slight upward motion; the general effect must be, however, to produce a mixing or churning rather than an upward motion.

The immediate effect of the explosion is to produce a miniature area of low barometer, caused by the radial rush of air towards the explosion centre, and by whatever ascending current that may result from the liberation of heat.

It would be reasonable to suppose that if the explosion produces any direct effect on atmospheric conditions, the area of low barometer should follow immediately, or nearly so, after the explosion. Have such changes in the barometric pressure been noticed to follow such mid-air explosion?

So far as the mixing motion is concerned, its action to produce a fall of rain must be slight. The ascending motion might cause a rainfall, but as this motion is slight in extent, its action under ordinary conditions, must at best be but insignificant.

In either case, any decrease in temperature, and consequent increase in relative humidity, must necessarily be slightly

decreased by the dry and heated gases evolved during the explosion of such substances as nitro-glycerine, dynamite or gunpowder.

It might be supposed from the above considerations that balloons containing an explosive mixture of hydrogen and oxygen would be preferable to those carrying nitro-glycerine dynamite or gunpowder, since in the former case the vapor of water results from the explosion, and in the latter dry gases. It must be remembered however, that the explosion of mixed oxygen and hydrogen produces, for the greater part, a collapse, or radial rush inwards *towards* the explosion centre, while the explosion of gunpowder or nitro-glycerine produces, for the greater part, a radial rush *from* such centre.

A circumstance that appears to have been lost sight of in all the recent attempts at rain-making, is that such attempts have been apparently made regardless of the hygrometric conditions of the air. As rain is but the excess of moisture, which the warm moist air when sufficiently cooled is unable to retain, the amount of the fall will depend, as already stated, on the quantity of moisture in the air as well as on the extent of the chilling action following the explosion or other cause. To attempt to produce rain by explosions in mid-air, irrespective of the quantity of moisture in the air, is to attempt to cause water to fall from the air when practically none is present. This is not only illogical but absurd.

It may be thought by some that the concussions caused by mid-air explosions might result in such a general movement of the surrounding air, as to cause rain to fall over an extended area. The flash of the explosion is followed by a sudden movement of the air causing the noise of the explosion. The phenomena of lightning and thunder are somewhat similar to those of artificial mid-air explosions. First we have the lightning flash, and subsequently the thunder which is a violent concussion of air. Does this concussion bring down a heavier rainfall? Popularly it is believed to do so, but the general opinion of the scientific world is that the lightning flash is the effect of a rapid condensation of

the aqueous vapor, *i. e.*, of a heavier rainfall, and not the cause of such a fall. That is to say the high potency of the lightning flash is due to the enormous decrease in the surfaces of the already charged rain drops over that of the surfaces of the thousands of the separate drops that coalesce to form the single drops.

Nevertheless, the liberation of heat energy and the rapid admixture of air following the disruptive discharge may slightly increase the rainfall, or may act as a determining cause of rain over an extended area.

There is this difference between the lightning flash and the flash of an explosion, viz: The former occurs over a comparatively great length of path, *i. e.*, a space of small breadth and depth but great length.

The latter occurs in a comparatively limited space, the three dimensions of which are nearly equal.

Though lightning is not a cause of rain, there can be no doubt that if rain can be artificially produced during a period in which there is much free electricity in the air, the storm will be attended by lightning and thunder. If then, there be any increase of rain due to the presence of lightning, artificial rain-making will be more liable to succeed when the potential of the air, as regards the earth or neighboring clouds, is comparatively high.

The enormous expenditure of energy required to produce a rain storm over an extended area is a circumstance that would appear to give but little encouragement to man's many efforts in this direction. The amount of energy liberated by the greatest explosion man has yet effected in mid-air, is but insignificant when compared to the energy liberated by nature during even a comparatively limited fall of rain.

There is, however, an important consideration, bearing on the question of the probable success of rain-making by mid-air explosions that gives to such attempts a far greater probability of success than would appear to be warranted from the facts already enumerated. Presupposing the existence of a sufficient mass of moist air, at preferably a comparatively high difference of potential

as compared with the neighboring air or the earth, a mid-air explosion might act as the determining cause of rainfall over a wide area, the balance of the energy requisite therefor, being supplied by the moist air. In a mass of very moist air there exists a store of energy which, if liberated, would suffice to cause movements of the air of vast extent. When the vapor of the air is condensed, the potential energy becomes kinetic, and, being liberated by the heat, causes ascending currents which produce a further condensation of moisture, and further liberation of energy previously locked up in the vapor.

There sometimes exist conditions in the air, in which it is, so to speak, in a state of very unstable equilibrium, and a slight determining cause may result in the liberation of the stored up energy with a resulting heavy rainfall. In such cases it would appear that there are no reasons why an explosion in mid-air should not be followed by rain. At the same time it is not unreasonable to suppose that the natural causes, which brought about such conditions, would, in many cases, continue to act and thus cause rain without artificial aid.

There are, however, meteorological conditions that probably frequently exist in certain latitudes in which heavy rains might be artificially produced by mid-air disturbances, when, without such disturbances, no rainfall would occur. Should, for example, a layer of warm, moist air exist between the earth's surface and a higher layer of cold, moist air, separated by a comparatively thin layer of air, and should such conditions exist as to maintain the two layers separate, then the breaking or piercing of the intermediate separating layer might permit such an up-rush of the warmer air through the opening, that the liberation of its stored up energy through the condensation of its moisture, would result in a general up-rush of the warm moist air and the consequent production of an extended area of low barometer. In other words, the artificial rupture of the separating layer would result in the formation of a true storm centre and a heavy rainfall of considerable dimensions. In such cases it would appear:

(1) That mid-air explosions will be more effective than explosions on the earth's surface.

(2) That directed mid-air explosions, *i. e.*, explosions in which the general effect of the liberated energy is to produce an upward rush of air, would be more effective than undirected, hap-hazard explosions.

If in such cases, considerable difference of potential exist between the layers of air, or between that of the air generally and the earth, the lightning flashes would unquestionably be effective in piercing the separating layer especially if, as would probably be the case, the general direction of the discharge be between the layers of cold and warm air.

Since, as we have seen, it is the ascending current that causes the heaviest rainfall, it would appear that mid-air explosions of such a character as to produce in general an upward rush of air would be probably more successful than undirected, hap-hazard explosions in mid-air. Such movements might advantageously be effected by the liberation of rockets with enlarged conical heads, or of any form of fire-work that would move generally upward.

Since success in artificial rain-making is probably dependent on the meteorological conditions, both of the lower and upper layers of the atmosphere, efforts should be made to enlarge our present very limited knowledge of such conditions.

Captive balloons, containing registering electrometers, tele-thermometers, tele-hygrometers, tele-anemometers, etc., might be connected by wires with recording apparatus placed on the earth's surface. The cost of maintaining such aërial stations of observation would be but insignificant when compared with the benefit that would accrue not only toward the solution of the problem as to the probable success in rain-making, but also in the aid given to the general operations of the United States Weather Bureau in particular, and to meteorology in general.

During the general prevalence of moist, warm air, when but a slight cooling is necessary to cause a general downpour, effective rain-making might be obtained by the sud-

den breaking or opening of cylinders of liquefied gases, where expansion would cause an intense chilling of the surrounding air; such cylinders could be readily opened by means of earth-controlled electro-magnets.

The following general conclusions may, in view of the present state of meteorological science, be properly drawn concerning the artificial production of rain.

(1) That rain can never be made to fall at will by mid-air explosions on any part of the earth's surface, irrespective of the climatic conditions there existing.

(2) That during certain meteorological conditions, mid-air explosions may result in rainfall over extended areas.

(3) That the liberation of energy necessary for such rainfalls is due not to the mid-air explosions, but to the energy stored up in the moist air from which the rain is derived.

(4) That the meteorological conditions which must exist for the successful action of mid-air explosions would probably, in most, though not in all cases, themselves result in a natural production of rain.

(5) That a comparatively high difference of electric potential between different parts of the air, or between the air and the earth, is possibly favorable when taken in connection with other meteorological conditions for artificial rain-making.

(6) That an undirected mid-air explosion is not as likely to produce rain, as an explosion in which the main tendency of the energy liberated is to cause a general up-rush of the air.

BOOK NOTICES.

Odontics; or, the Theory and Practice of the Teeth of Gears. By George B. Grant. Published by the Lexington Gear Works, Lexington, Mass., 1891. pp. 103.

This is called a working course of study, and the beginner is advised to first master certain sections, as the introduction says it is not necessary that the student, especially if he is a workman, should learn all that is taught in this book. Taking up the matter as directed is pretty hard work for any one, and it is doubtful whether a student would progress very far before deciding that he has had enough. For instance, the third paragraph introduces him to "axoids, "hyperboloid of revolution" and the next to "normal surfaces."

There is a radical defect in the work from a student's standpoint, which is not an uncommon one in books written by men full of their subject—and that is that the student is expected to take the author's statements as facts without proofs or reasons; for instance, in Section 11 the author states that "With the above conditions given we can deduce the following law: *The common normal to the tooth curves must pass through the pitch point.*" The conditions spoken of are not at all clearly set forth, and a student surely would like to know how such a law can be deduced. This is the author's method throughout the work. As to the parts to be taken after reading the easier portions it is even more difficult, as early in the book the reader is obliged to handle differential equations.

But the work is, nevertheless, an excellent one, as the matter in it is very valuable, and no one having some knowledge of gear wheels can fail to get new ideas from reading it.

The first part of the work is devoted to the general theory of tooth action, defining and explaining the terms used, the methods of constructing tooth curves by points, and of forming teeth mechanically.

The second part treats of spur gears, explaining circular and diametral pitch, giving actual sizes of various pitches, explaining and giving value for the addenda, clearance, etc., explaining the author's method of dividing a series of gears into intervals, each having the same shaped teeth, and determining the ruling size for each interval. The author also treats of the efficiency and strength of teeth and the power that can be transmitted.

In part third the subject of involute teeth is taken up, methods are given of laying down the gears and the applicability to symmetrical and unsymmetrical teeth, and numerous formulæ are given.

Part fourth treats of cycloidal teeth, the author paying his respects to the fossils who persist in using cycloidal teeth when involute are so much better. The subject is more satisfactorily presented than any other portion of the book. The descriptions and explanations are clear and to the point, and there is not too much of them.

The next part takes up the pin-tooth system, and is rather difficult to understand in some parts.

Part six treats of twisted, spiral and worm-gears; part seven of irregular and elliptic gears; part eight of bevel gears, and part nine of skew bevel gears. The matter in these parts is what an elementary work on gearing should contain, and excepting the small amount of mathematics can be readily handled by any one interested.

Throughout the work many of the mechanical details of actually laying out and manufacturing the gears are given, and the author has made use of about all the available experiments relating to efficiency, and pointed out the desirability of much more information in this direction.

As the matter was originally contributed to the *American Machinist* it is divided into short paragraphs under sub-heads, each paragraph extending over both columns of the page, thus making the book look and read disjointedly. There is, unfortunately, no index and no table of contents, so that it is inconvenient to refer to. H. W. S.

Car Lubrication. By W. E. Hall, B.S., M.E., New York: John Wiley & Sons, 53 East Tenth Street. 1891.

This little work, the outcome of recent studies by the author, is designed to throw light upon "some of the knotty problems which were then presented" to him.

The author recognizes the inapplicability of the ancient "three laws of friction" to lubricated surfaces; and, availing himself of the results of the modern investigations of Prof. Thurston and others, proceeds, in eminently practical fashion, to state the case as it appears to-day.

The theory of friction of lubricated surfaces is concisely stated, after which follow chapters devoted respectively to a review of experiments for determining coëfficients of friction for such surfaces, to the metals used in bearings and the oils for lubricating them, to methods of lubrication, to the construction of journal boxes, to the cost of lubrication and to the heating of journals.

The author inclines to skepticism as to the value of mechanical devices for improvement of lubricating methods, and believes that "the present method is by no means an imperfect one when the best is made of it."

T.

Retaining Walls for Earth. Including the Theory of Earth Pressure as Developed from the Ellipse of Stress. With an appendix presenting the Theory of Prof. Weyrauch. By Malverd A. Howe, C.E., Professor of Civil Engineering, Rose Polytechnic Institute. Second edition, revised and enlarged. New York: John Wiley & Sons, 53 East Tenth Street. 1891.

We quote from the preface:

"The first edition of this work was based upon the theory advanced by Prof. Weyrauch in 1878, but owing to the length of the demonstrations used by him, it was thought advisable to present different and shorter demonstrations in this edition. To show that the new demonstrations give identical results with those obtained by Prof. Weyrauch, his demonstrations have been given in an appendix as they appeared in the first edition.

"The new demonstrations are based upon the theory first advanced by Prof. Rankine in 1858."

Part I, of the present work, gives formulæ for earth-thrust, breadth of base of wall and depth of foundations, and Part II contains demonstrations of these formulæ. An appendix of four chapters gives Prof. Weyrauch's Theory of the Retaining Wall, taken from the *Zeitschrift für Baukunde*, references to authorities, a diagram for one of the values used in the formulæ, and tables of weights of masonry and backing, of angles and coëfficients of friction (from Rankine) of certain complex quantities used in the formulæ, and of natural trigonometrical functions.

The treatment, based as it is upon the works of Weyrauch and Rankine, is, of course, intensely mathematical, and no doubt of great interest from the scholastic point of view, and of value, too, notwithstanding the discussions among the professors as to what constitutes the true theory. To the "prac-

tical man," the usefulness of such studies must be prejudiced by the facts stated on p. 10, that a change of a few degrees in the value of the angle of repose sometimes causes a large change in that of the earth pressure, and that the former value must be "determined or assumed." In the language of an engineer of the last generation:

"The young engineer need not in practice concern himself particularly about the precise specific gravity of his backing, or about the angle of slope at which it will stand; for the material which he deposits behind his wall one day may be dry and incoherent, so as to slope at one and one-half to one; the next day rain may convert it into liquid mud, seeking its own level like water; the next it may be ice, capable of sustaining a considerable load, as a vertical pillar.

"Moreover, he cannot foretell what may be the nature of his backing; for as a general rule, this must consist of whatever the adjacent excavation may produce from time to time; sand to-day, rock to-morrow, etc. Retaining walls are, therefore, usually built before the engineer knows the character of their backing."

Hence, "the young engineer" may perhaps be pardoned for a feeling of modest hesitation in grappling with a proposition like equation (1), according to which, in the general case of inclined earth surface and inclined back of wall, the earth pressure is:

$$E = \frac{H^2 \gamma}{2} \frac{\cos(\varepsilon - \alpha)}{\cos^2 \alpha \cos \varepsilon}$$

$$\times \sqrt{\sin^2 \alpha + \cos^2(\varepsilon - \alpha) \left\{ \frac{\cos \varepsilon - \sqrt{\cos^2 \varepsilon - \cos^2 \phi}}{\cos \varepsilon + \sqrt{\cos^2 \varepsilon - \cos^2 \phi}} \right\}^2 + 2 \sin \varepsilon \sin \alpha \cos(\varepsilon - \alpha) \left\{ \frac{\cos \varepsilon - \sqrt{\cos^2 \varepsilon - \cos^2 \phi}}{\cos \varepsilon + \sqrt{\cos^2 \varepsilon - \cos^2 \phi}} \right\}}$$

in which ϕ is this very uncertain and variable angle of repose.

An admirable feature (a well-nigh indispensable one, indeed, in a work of this kind) is the list, preceding the discussion, of the symbols used, with their meanings. A similar list follows (why does it not also precede?) the account of Weyrauch's theories. T.

The Chronicle Fire Tables for 1891: A record of the fire losses in the United States by risks, States and causes during 1890, etc., and much other interesting and valuable information for fire underwriters. New York: The Chronicle Company, Limited. Price, $5.

This valuable and elaborate annual account of data, pertaining to fires in the United States, is fully equal to former issues, and gives evidence of immense labor in the gathering and correct presentation of the number,

causes, and the amounts of losses from fires during 1890. Each year as knowledge extends among city and town authorities, underwriters and manufacturers, of scientific efforts to understand, repress and combat fires, the greater is the desire, among an increasing number of persons, for such a series of reports as this one represents. Their value augments with the number of their years.

This volume contains 311 pages, royal 8vo, of fine paper with superior binding. Besides a general review of the fires occurring in the United States during 1890, there are presented nine full-page diagrams showing the movement in fire losses for sixteen years, and the monthly curves of incendiarism and its geographical distribution (by shading of States) for seven years, 1884–1890, inclusive. The principal tabulation of the volume gives the number of fires during 1890 by classes of risks, with property loss, insurance loss and causes of fires. There is presented an extended tabulation of fires during 1890 *by causes* (also a similar one *by States and Territories*) giving the number of fires, the exposures, property and insurance loss on original risks, property and insurance loss by exposures, with notes where fire originated.

The tabulations named will be sufficient to show the great labor required, the minutiæ of data and their consequent value; but there are others almost equal thereto, such as risks burned in the United States during the sixteen years, 1875–1890; monthly losses by fires, given by States and Territories; increase in the urban population of the United States; comparative table of fires and failures in business (very suggestive); losses by fire in each State and Territory during the fifteen years, 1876–1890; analysis of the causes of 171,139 fires in the United States, during six years, occasioning property loss, $670,952,891; aggregate annual fire losses in the United States for the sixteen years 1875–1890, etc.

We cannot too much commend this admirable statistical work. It is well worthy a place in the library of every insurance company in the world; also in that of every merchant, manufacturer and attorney-at-law. It will well repay careful study; and its cost is small compared with the expense of its production and the advantages it offers of knowledge on a most important subject, interesting every property-holder. N.

Franklin Institute.

[*Proceedings of the stated meeting, held Wednesday, Sept. 16, 1891.*]

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, Sept. 16, 1891

Mr. W. P. TATHAM, Vice-President, in the chair.

Present, ninety members and eight visitors.

Additions to membership since last report, eleven.

On the recommendation of the Board of Managers, Prof. George Forbes, of London, England, was elected an honorary member of the Institute.

The Actuary reported a vacancy in the Board of Managers, caused by the death of Mr. John J. Weaver. Mr. John C. Trautwine, Jr., was thereupon elected to fill Mr. Weaver's unexpired term of office.

The Secretary reported that by the resignation of Mr. Wm. B. LeVan and the death of Mr. Louis H. Spellier, two vacancies had been created in the Committee on Science and the Arts. They were filled by the election of Mr. J. M. Emanuel for the unexpired term of Mr. LeVan, and of Mr. Spencer Fullerton for the unexpired term of Mr. Spellier.

The Secretary was directed to prepare suitable memorials of Mr. J. Luther Ringwalt and Mr. Louis H. Spellier, recently deceased members.

Lieut. Bradley A. Fiske, U.S.N., presented a paper on his "Range Finder," an instrument of precision, designed for finding the distance and position of an object, more especially of a vessel at sea. The paper was suitably illustrated by diagrams projected on the screen.

At the conclusion of the paper, Mr. H. R. Heyl, referring to the highly ingenious features embodied in the inventions, and to their obvious importance, moved that the subject be referred to the Committee on Science and the Arts for investigation and report. Carried. (The paper was referred for publication.)

Mr. C. J. Hexamer presented a brief communication, with illustrations, exhibiting a method that he had proposed and employed for verifying the manufacturing census of a city. The communication elicited some discussion between Mr. Henry Bower (Assistant in charge of the collection of the statistics of chemical manufactures for the eleventh census) and the author.

The Secretary's report contained some comments on current matters of technical interest, including a reference to a suite of interesting specimens illustrating the process of electric forging devised by Mr. Geo. D. Burton, of Boston.

Mr. W. N. Jennings presented a suite of lantern slides in continuation of his series of local pictures.

Adjourned. WM. H. WAHL, *Secretary.*

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FIG. 1.

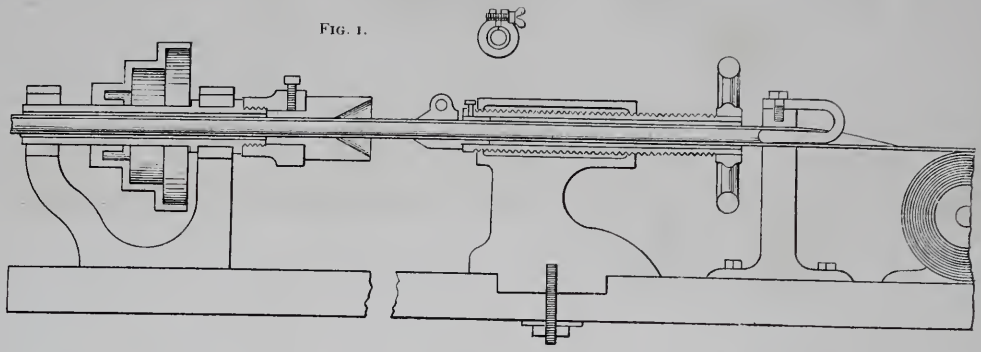


FIG. 2

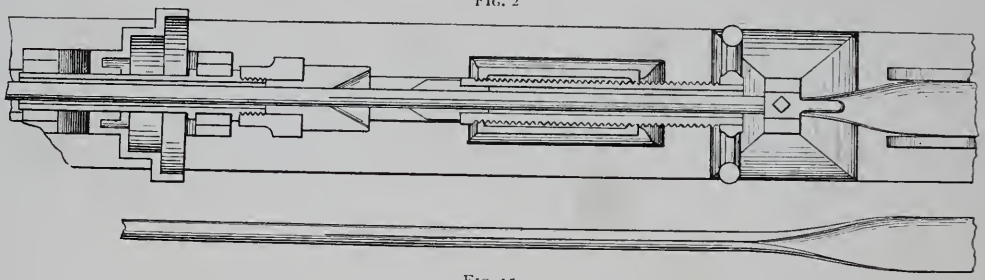


FIG. 15.

FIG. 17.

FIG. 16.

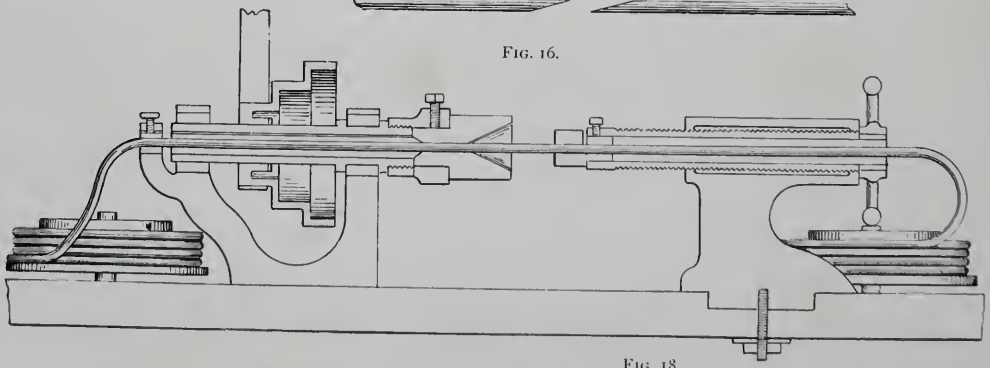


FIG 18.

FIG. 3.

FIG. 19.

FIG. 20.

JOURNAL

OF THE

FRANKLIN INSTITUTE

OF THE STATE OF PENNSYLVANIA.

FOR THE PROMOTION OF THE MECHANIC ARTS.

VOL. CXXXII. NOVEMBER, 1891. No. 5

THE Franklin Institute is not responsible for the statements and opinions advanced by contributors to the *Journal.*

BEVINGTON'S PROCESS OF WELDING METALS AND SPINNING AND SHAPING TUBES.

[*Report of the Committee on Science and the Arts.*]

[No. 1,647.] HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, September 3, 1891.

The Sub-Committee of the Committee on Science and the Arts, constituted by the Franklin Institute, of the State of Pennsylvania, to whom was referred, for examination,

JAMES H. BEVINGTON'S IMPROVED MODE OF WELDING METALS AND SPINNING AND SHAPING TUBES,

report, that this is the invention of which a very handsome display of products was exhibited at the stated meeting of the Institute, on the evening of June 17, 1891, and which was referred to the Committee on Science and the Arts by resolution of the Institute for examination, and if proper, for award.

The process herein described is owned and operated by

the New Process Welding and Spinning Company, 21 Rialto Building, Chicago, by whom it has been very intelligently developed.

The invention is the subject of United States Letters-Patent, No. 44,472, dated January 13, 1891, and of two subsequent applications for United States Letters-Patent, which have been examined and allowed, but are not yet published.

The invention consists in forcing strips, rods or tubes of ductile metal into converging revolving dies of harder metal, in which it becomes heated and compacted and acquires the shape of the interior of the die.

By employing a converging forming guide, the opposed surfaces of the ductile metal guide together like the binding guide of a sewing machine, and a tube may be made from a strip of ductile metal which, passing through a hollow non-rotating sliding arbor in which it is clamped firmly, it is forced into a funnel-shaped steel die, and becomes welded so soundly, that the seam is of equal strength with the rest of the metal, and in fact, cannot easily be detected without inspecting the interior surface.

Instead of supplying the strip of metal endwise, with edge parallel with the axis of the tube, the strip may be introduced obliquely, and wound helically on the tube, the welding operation being conducted in the same manner in the converging die, seamless tube being the result.

Separate wires, with the ends scarfed, placed in a similar die and similarly located, become firmly welded. No fluxes are either used or required. Tubes are reduced in diameter and extended in length by this process, and, what appears remarkable, although no core is used to sustain the metal internally, the thickness of the metal of the tube, when reduced in diameter, remains, without any material variation, the same, and the degree of temper, or hardness and elasticity of the metal do not appear to be impaired by this process.

The apparatus is shown in the accompanying engravings reproduced from the drawing of the inventor's specification.

The first illustration shows the application of the invention to contracting, and closing and welding the ends of

tubes. *Fig. 1* represents a sectional elevation of a lathe for spinning tubes or other straight articles according to this method. *Fig. 2* represents a horizontal longitudinal section of the same in the plane of its axis showing the die or former used in the process of reducing a metal tube to one of

FIG. 3.

FIG. 5.

FIG. 4.

FIG. 14.

FIG. 13.

FIG. 12.

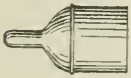


FIG. 11.

FIG. 10.

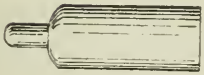


FIG. 9.

FIG. 8.

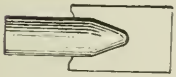


FIG. 7.

FIG. 6.

smaller diameter. It also shows the tube before being operated upon. *Fig. 3* is an end elevation of the die or former. *Fig. 4* shows a lengthwise section of the die and also a tube before reduction. *Fig. 5* shows the tube and die after the tube has been operated upon. *Fig. 6* is a longi-

tudinal section of a die where it is desired to close the end of the tube. The tube is also shown. *Fig. 7* is a view showing the operation completed. *Fig. 8* represents the die used to weld two tubes together for the purpose of lengthening the same.

Figs. 9, 10, 11, 12, 13 and *14* represent some of the different results accomplished by the process of reducing and increasing the diameter and closing the ends of the metal tubes. *Fig. 15* shows a detached view of a tube as partially formed from a strip of metal. *Fig. 16* shows the invention as applied to welding the ends of wires or rods.

The machine adapted to carry out this process is substantially a lathe, with hollow arbors in both the head and tail stocks. A conical die is secured upon the inner end of the hollow arbor of the head stock so as to turn with it. This die is of very hard metal, and has a central perforation running through it, conical or flaring at each end, the opening at the inner end being much larger than the one at the other end.

The hollow spindle of the tail stock is screw-threaded and is mounted in a threaded bearing so that it can be set in and out, for which purpose it is provided with a hand wheel. A contractible clamp is set in the inner end of this arbor, which is adapted to hold the rod or wire from turning as well as lengthwise.

The engravings show this machine in operation upon wires. The two wires are preferably prepared by scarfing or by cutting the ends upon an incline, as shown in *Fig. 17*, so as to give each a corresponding bevel. One of the wires is thrust through the hollow shaft and part way through the die, and the wire is fastened in this position by means of the clamp at the rear of the head stock. The other wire is inserted in the tubular spindle of the head stock and passed out through the clamp a little way, and is then firmly secured in place by means of this clamp.

The arbor of the tail stock is then fed inward until the bevelled end of the wire is forced into the die and brought firmly against the bevel of the other wire. The die is then very rapidly revolved by the means already explained,

while, of course, the two wires are held in a fixed position and forced together. During this rapid movement of the die, a very high degree of heat is developed by frictional contact, which is of sufficient intensity to heat the two ends of the wire to a welding heat and perfectly weld them together along their contact faces. The union thus obtained is as complete and perfect as a welded joint can well be made, and, owing to the action of the die, the joint is smooth and in fact almost imperceptible, the finished wire presenting the appearance of a smooth cylinder seen in *Fig. 18*.

Obviously, with the machine constructed as described above, the wire, after being welded, must be drawn through at one end of the machine. For this purpose the wires are wound upon spools at each end of the machine. After welding, the wire may be drawn through, being run off from one spool and wound upon the other, the clamps, of course, being loosened for this purpose, and so length after length of wire may be joined together to form a line of any length desired.

Two rods may be welded together in the same way, one being set in the head stock and the other in the tail stock, and both clamped as described.

The operation will be understood without any further explanations, the rod set in the tail stock being fed up forcibly against the end of the opposite rod.

This process of welding may be successfully applied to wires and rods of very considerable size; the process has been practically tested with entirely satisfactory results on rods of different sizes, up to one inch in diameter, and probably may be carried on successfully with even larger sizes.

The invention is applied to forming tubes of metal, as shown in *Figs. 1* and *2*.

The machine used is a lathe, as previously described, with some additional features. The tail stock is hollow and suitably threaded to serve as a feeding device, for which purpose it is provided with a hand wheel on its outer end. A clamp is set in the inner end of the arbor of the tail stock,

being of any suitable construction to clasp and firmly hold a round tube. It is shown in *Fig. 19*, in the well-known form of a divided ring with a screw for the purpose of drawing the two parts together. A standard is mounted upon the bed beyond the tail stock, and on this standard is mounted a mandrel which corresponds in size to that of the required tube.

This mandrel extends just through the standard, which is provided with an aperture for this purpose, a little larger than the mandrel, its diameter corresponding to the outer diameter of the tube. At its outer end, the mandrel is bent upward and backward upon itself, and this upper turn or member is fastened to the top of the standard by means of a screw body as seen in *Fig. 1*, or in any other suitable way. The metal plate from which it is intended to form the tube, is cut into a strip or strips of such width as to form a tube of the desired size, when rolled up in a circular form with the opposite edges brought together; this strip or strips may be wound upon a suitable drum a little in front of the mandrel standard, where the strip is shown wound or coiled upon the drum, the latter being free to turn its axis so that the strip may be run off.

The operation is as follows: the metal strip wound upon the drum as described, is led thence through the aperture in the standard, bent around the mandrel, by which operation it is formed up around the mandrel in the shape of a tube, the edges of the plate being brought close together, but of course not joined.

The end of this unclosed tube is carried along the tail stock; and in the revolving die, the clamp is then closed tightly upon the tube, and the revolving die set in motion. The tail stock, which, in the first instance, is drawn back as far as possible, is now set up gradually, thus feeding the unclosed tube into and through the revolving die, and by the action of the hard-faced conical die, rapidly revolving, the tube is heated to a welding heat, and the edges thoroughly and completely welded together, thus closing the joint and leaving a perfectly smooth and finished surface.

The feeding of the tube through the die will, of course,

draw the strip from the drum and through the forming aperture in the standard, thus continuously forming up the tube around the mandrel during the feeding operation. With the device here shown, it is obvious that when the limit of the feed movement of the tail stock is reached, the clamp must be loosened; the tail is again retracted, the clamp refastened, and the feed forward is again made. The tube, delivered from the hollow shaft will be a completed product, with the joint perfectly closed and smoothly finished by the action of the die, so as to present a seamless appearance. It is evident that the metal from the drum to the hollow shaft will present three different conditions; the first section between the roll and forming mandrel, is straight, but with its edges gradually turning upward and inward, as seen in *Fig. 2*, and the second section, between the mandrel and the revolving die, will be in the form of an enclosed tube, as indicated in *Figs. 2* and *15*, while the last section, beyond the revolving die, will be a finished tube.

It will be seen that in carrying out the process with the apparatus herein shown and described, the feed is intermittent, but that a tube can be made of any length desired. It is also evident that if a feed mechanism were applied to the tube by which the metal would be drawn through the machine by a slow continuous movement, the action of the devices would be constant, there being no intermission in the feed. Sections of welded specimens show the weld to be perfectly solid and fully equal in strength to the rest of the material.

The capacity of this invention for uses in the arts seems to your committee as almost unlimited, when circular forms of ductile metal are required. The series of helically coiled or twisted wires welded as shown in *Fig. 20* is one of the many interesting specimens produced by this invention.

It has already been applied commercially, with satisfactory results, to cartridge cans for dynamite projectiles, and, so far as your committee can judge, develops fully the best strength of the material.

The invention appears entirely novel, is simple and

easily managed and economical, and does not require a very costly plant, and in the opinion of your sub-committee deserves recognition by the award of the Elliott Cresson Medal.

LUTHER L. CHENEY, JOHN HALL,
FRANCIS LECLERE.

Adopted, September 2, 1891.

S. LLOYD WIEGAND,
Chairman of the Committee on Science and the Arts.

GOETZ-MITCHELL SYSTEM OF ANCHORING BEAMS IN BUILDING CONSTRUCTIONS.

[*Report of the Committee on Science and the Arts.*]

[No. 1,639.] HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, September 3, 1891.

The Sub-Committee of the Committee on Science and the Arts, constituted by the Franklin Institute of the State of Pennsylvania, to whom was referred for examination,

THE GOETZ-MITCHELL SYSTEM OF ANCHORING BEAMS IN BUILDING CONSTRUCTIONS,

report, that this invention is the subject of, and is fully described in, letters-patent of the United States granted to Mansell Mitchell and Henry A. Goetz, numbered and dated, respectively, 386,976, dated July 31, 1888; 387,004, dated

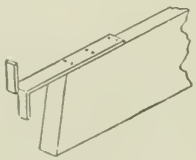


FIG. 1.

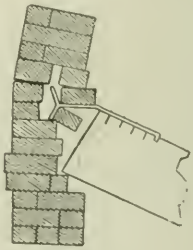


FIG. 2.

July 31, 1888, and 437,592, dated September 30, 1890; these are appended and form part of this report.

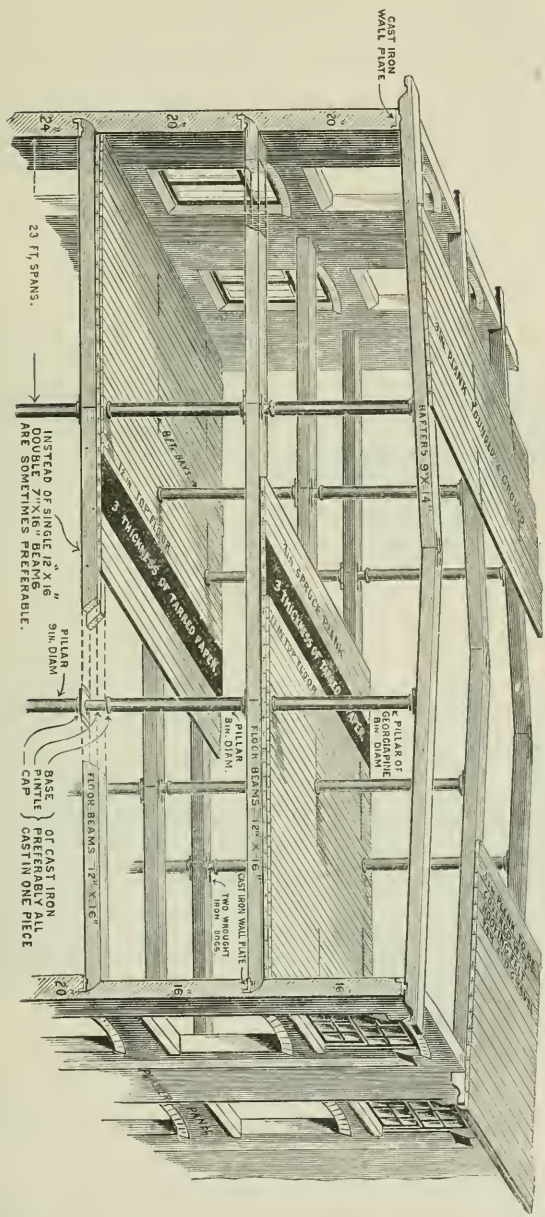

CAST IRON WALL PLATE
RAFTERS 9"X14"
3" THICKNESS OF TARRED PAPER
3" THICKNESS OF TARRED PAPER
PILLAR OF GEORGIA PINE 8IN. DIAM
PILLAR 8IN. DIAM.
FLOOR BEAMS 12" X 16"
CAST IRON WALL PLATE
TWO WROUGHT IRON DOGS
FLOOR BEAMS 12" X 16"
23 FT. SPANS.
INSTEAD OF SINGLE 12" X 16" DOUBLE 7"X16" BEAMS ARE SOMETIMES PREFERABLE.
PILLAR 9IN. DIAM
BASE
PINTLE
CAP
OF CAST IRON PREFERABLY ALL CAST IN ONE PIECE
PINE

FIG. 3.

This invention does away with the objectionable features of the usual method of anchoring beams, and is, in the opinion of your committee, a decided improvement on the present "standard" method of constructing floor beams, with cast-iron wall plates and base, pintles and caps (cast in one piece) employed first by the New England Factory

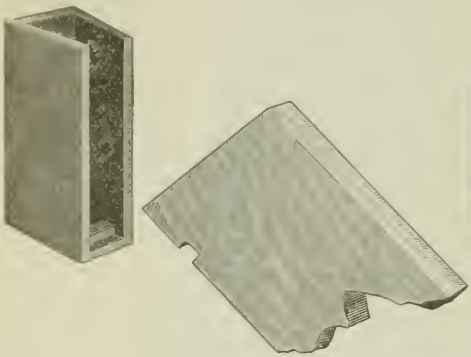


FIG. 4.

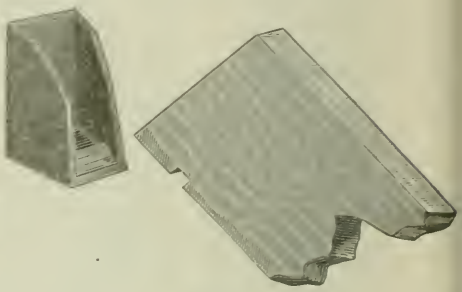


FIG. 5.

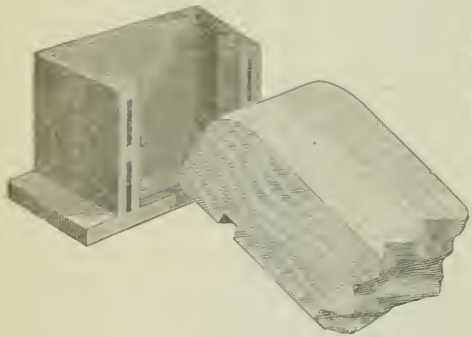


FIG. 6.

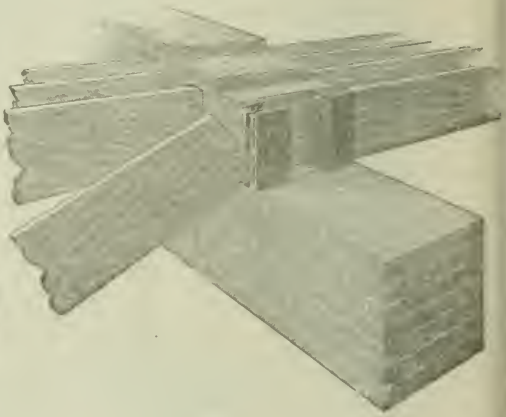


FIG. 7.

Mutual Insurance Companies, and now generally employed in manufacturing establishments built on the "*slow-burning principle*."

In order properly to understand the value of this invention, your committee calls attention to *Fig. 1*, showing one of the old methods of anchoring beams; *Fig. 2*, showing

the effect where a beam so anchored burns through. (Taken from the *Indicator*, Detroit, Mich., December, 1889.)

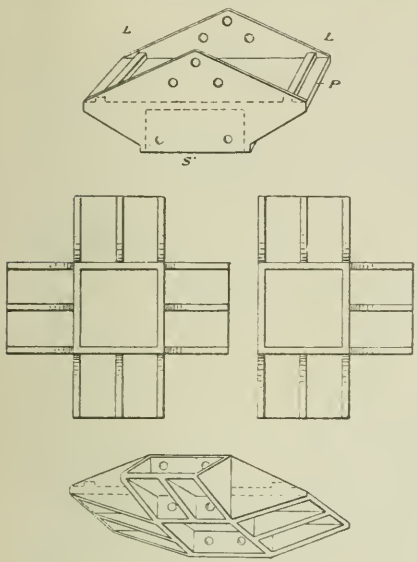


FIG. 8.

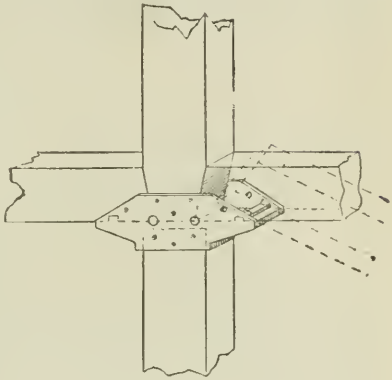


FIG. 10.

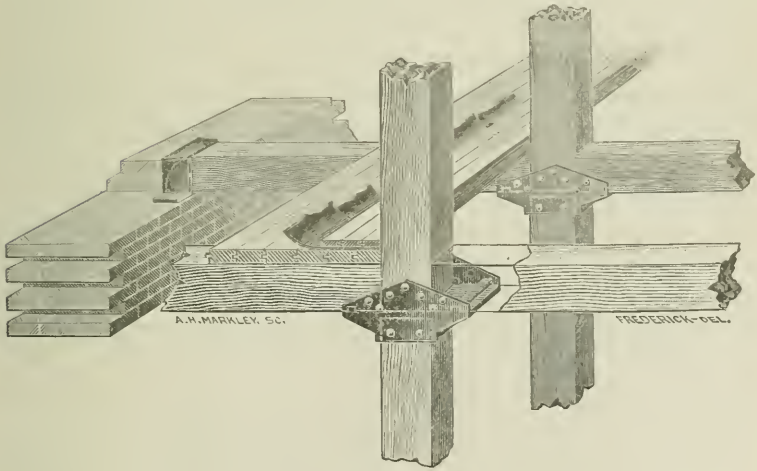


FIG. 9.

Fig. 3 shows a standard "slow-burning" building construction.—(Taken from John R. Freeman's paper, presented September 17, 1890, "Comparison of English and Ameri-

can Types of Factory Construction," in the *Journal of the Association of Engineering Societies*); and lastly, *Figs. 4* to *10*, which show the Goetz-Mitchell Method.

In view of the fact that this is an improvement on former methods, and will tend, if generally introduced, to lessen our enormous annual fire waste (which for years has annually been between $100,000,000 and $128,000,000) your committee recommend the award of the John Scott Legacy Medal and Premium to the inventors.

C. JOHN HEXAMER, *Chairman*,
THOMAS P. CONARD,
STACY REEVES.

Adopted, September 2, 1891.

S. LLOYD WIEGAND,
Chairman of the Committee on Science and the Arts.

A COMPARISON OF FIFTEEN AMERICAN VARIETIES OF SOLID EMERY WHEELS.

Among the matter for publication submitted to the Committee in charge of the *Journal of the Franklin Institute*, October 7th, were the advance sheets of a report made to a private manufacturing company on the comparative value of fifteen varieties of solid emery wheels, the comparison having been made by Prof. Coleman Sellers, Prof. J. E. Denton and Mr. Alfred R. Wolff, who were associated in the inquiry at the instance of one of the wheel makers.

In view of the paucity of literature on this subject and as bearing upon a lecture delivered December 9, 1889, by Mr. T. Dunkin Paret, before the Franklin Institute, the committee decided to publish the greater part of this report in the words of its authors.

After stating how the authors became associated in this inquiry the report continues as here follows:

Our first object was to settle the question as to what constitutes a good solid emery wheel.

Our second object was to establish test conditions of such scientific accuracy as to prevent any doubt of the results.

Our third object was to give thorough trial, under uniform test conditions, to the various wheels, and to secure a mass of exact data.

The investigation thus outlined has been of the most painstaking and thorough character, and has lasted about two years.

Having determined on the qualities which constitute a good solid emery wheel, we established our own conditions of test, and submitted to such conditions wheels of our own selection.

The wheels of fifteen different manufacturers were selected. These were:

Celluloid,	Lehigh,	Tanite,
Crystal,	Norton,	Union stone,
Detroit,	Northampton,	Vitrified,
Grant,	Norwich,	Vulcanite,
Hampden,	Sterling,	Waltham.

Among these fifteen varieties only one compared favorably with the Tanite wheel, the latter having easily beaten all competitors save one. The comparative values of the Tanite and its single rival will have to be ascertained by further trials.

After careful study of the literature relating to grinding processes, we witnessed actual grinding by solid emery wheels in various factories; then, in company, twice visited the works of the Tanite Company, and observed a series of trials with Tanite and other wheels, in which the metal was in some cases applied by hand pressure, and in other cases, without such pressure upon machines built expressly for testing purposes. It was unanimously agreed that hand-testing must be done away with and the personal factor eliminated, in order that the results might be unimpeachable. The defect of existing test machines was speedily recognized, and it became necessary to invent a new testing machine. After much study and many trials, with the valuable assistance of Prof. J. Burkitt Webb, we constructed a machine which met the approval of all concerned.

This machine was so constructed that the wheel and work were brought in contact by definite and measurable

pressure without any obstacle being interposed to the free wear of either metal or wheel. The results approximated closely to those obtained by hand-pressure, and yet were independent of all influence from the operators of the machine. The power consumed was measured by a dynamometer attached to the driving shaft and the speed recorded by a tachometer. The resistance between wheel and metal was indicated continually by a standard scale.

After many preliminary trials with this machine its results were compared with those obtained by individual operators under various conditions, and experiments with skilled workmen, expert grinders, were made.

It was agreed, that to constitute a good solid emery wheel, the following qualities should be combined; safety under the widest conditions of use and misuse; rapidity of cut; freedom of cut at moderate pressure; reasonable amounts of wheel loss and power consumption; evenness of wear; general staying quality; and reliability under the widest range of circumstances.

We then agreed upon a programme of work—had the test machine erected in the machine shop of the Stevens Institute of Technology at Hoboken—and had the various wheels (bought directly by themselves in the the open market) delivered there. The grinding was done on cast-iron bars supplied directly to us by one founder, special care being taken as to quality of metal and size of bar. The trials reported on were made at the Stevens Institute during 1889 and 1890, the tabulations being too voluminous to admit of detail here.

In preliminary and collateral investigation many trials were made with hand pressure, and some under measured pressures of ten pounds and seventy-five pounds; but our report is based on a long series of trials at three different pressures—forty-two pounds, sixty pounds and 100 pounds. These separate trials numbered several thousand, during each of which exact data were recorded as to speed, power, resistance between wheel and metal, amount of metal ground off, amount of wheel material consumed, and observations made as to the cleanness of cut, amount of heat

generated, amount of glazing or clogging up of wheel with metal, and as to cracks, breaks and defects of wheels.

Of the fifteen varieties six were found too unsafe to warrant their general use, fifty-seven per cent. of the wheels bursting under the same conditions which other wheels passed through uninjured. Eleven varieties (among which are included the six unsafe varieties) were found to be such slow cutters that the average metal removal of ten of them was less than the general average of all the wheels. Of the fifteen varieties only four were found to be rapid cutters. Of these one wore so rapidly that the cost of its rapid cut was unreasonable. This left three, safe, effective and satisfactory wheels, one of which, however, was demonstrated to work at a greater cost than the Tanite. The rivalry was thus narrowed to two wheels, and, in the judgment of our board, further trials are necessary before the relative value of these two can be determined.

One striking feature characterized these two. That is, that in every series of trials these wheels increased in productive capacity, the average of the last cuts of all the series being greater than the average of all the first cuts. The thirteen other varieties all decreased in productive capacity, the average of the last cuts being less than the average of the first. Some of these which made a brilliant show at the start, cut scarcely anything at the close.

Our investigation satisfied us that the ordinary user of solid emery wheels is likely to be deceived as to the productive capacity of such wheels and the cost of product if he trusts to mere appearances, and that the real value of any solid wheel can only be fixed by an investigation which gives exact data and covers a wide range of observation.

Such an investigation ours has been, each fact being observed and attested by several independent witnesses trained to scientific observation, and each calculation and measurement being passed through and checked by several hands.

This investigation demonstrates the unquestionable superiority of the Tanite wheel to thirteen out of fourteen competitors.

As nearly all the preliminary and collateral trials were made with Tanite wheels more than three times as many of these were used as of any other make. In all this use, under every degree of measured automatic pressure and under the heavy pressure of long bars used by hand (a test applied to no other wheel) and also at a speed nearly double that of any other wheel save one, *no Tanite wheel burst or broke.* The safety of the Tanite wheel can be considered unquestionable. The cutting power of the Tanite wheel did not deteriorate with use, its average last cuts always exceeding its average first cuts. The Tanite wheel cut well at moderate pressure.

The consumption of power and of wheel material is such that, taking into account the cost of labor and all other items entering the problem, the Tanite wheel does its work at a very low cost.

In the use of all tools and machines, consideration should be given to their regularity and uniformity of action and to their freedom from such stoppages as arise from a variety of undefined and unforeseen causes. From a great variety of causes many of the competing wheels failed to complete their series of trials, and gave rise to frequent incidental stoppages. Such was not the case with the Tanite.

As evidence of these facts, thus summarized and stated in a general manner, we possess an overwhelming mass of exact data in the form of numerical tabulations. These details are reserved for future publication.

COLEMAN SELLERS,
J. E. DENTON,
ALFRED A. WOLFF.

THE DEVELOPMENT OF THE PIG IRON MANUFACTURE IN THE UNITED STATES.*

By JOHN BIRKINBINE,
President, American Institute of Mining Engineers.

Few articles which we manufacture have been so liberally discussed by political economists as pig iron, and in legislation concerning our customs duties, this product has assumed such a prominent position that we may infer that this particular industry is recognized as exerting a marked influence upon the progress of the country at large, and especially upon certain sections thereof. Facts sustain this inference and probably no one industrial pursuit, except possibly coal mining, has done more to advance the United States than the manufacture of pig iron and by this manufacture much assistance has been given to the great development of the coal mining industry, a development which now contributes about 150,000,000 tons annually, or thirty per cent. of the world's output of coal.

To trace the practical growth of pig iron production we need not go back 270 years to the first unsuccessful attempt at iron manufacture in Virginia, nor discuss the pioneer iron works erected at Lynn, Mass., in 1643, to treat the bog ores occurring near the coast, nor those following in Connecticut, Rhode Island, and New Jersey, nor need we recite the history of the older plants in New York, Pennsylvania, Virginia and Maryland, whose business records are associated with the history of the nation's struggle for independence. In this connection, attention may well be invited to the fact that much of the earlier advancement in iron production and manufacture was based upon the use of bog ores, which abound along the Atlantic seaboard but which are now lightly esteemed

* A lecture delivered before the Franklin Institute.

and employed to a limited extent only, on account of their lean character and scattered deposits.

A majority of the men now living have seen the years which mark the commercial development of this industry, and the last two decades and a half are the most pronounced in remarkable results. Beyond, therefore, a mere statement indicating the earlier growth of the pig-iron industry and a few remarks upon it, no effort will be made to discuss the subject of development for a period beyond twenty-five years.

This lecture will briefly summarize the progress made in the past twenty-five years in pig iron production in the United States, with reasons therefor, and give contemporaneous data as far as obtainable from other nations which make large outputs of this metal.

It will note the distribution of this industry in different sections of this country, and the relative advance made by each, and also call attention to the prominent position which Pennsylvania has occupied, and the preëminence the State has now attained.

It will also indicate the probable future growth of pig iron production, and discuss, in a general way, the prognostications as to a future situs of pig iron productions.

No attempt will be made to trace the industry beyond the primary process of producing pig iron, nor will any reference be made to the obvious influence which governmental protection has upon its development.

GROWTH OF THE INDUSTRY.

Mr. James M. Swank, in his reports to the American Iron and Steel Association, states that the total output of pig iron in 1810 was 54,000 gross tons, increasing threefold to 1830, when it was 165,000 gross tons, and this again twofold to 1840, when it reached 286,903 gross tons; the output for 1850 being 563,755 gross tons, and for 1860, 821,223 gross tons.

These figures show that, while the production of 1860 was less than one-eleventh that of last year (1890, when 9,202,703 tons were made), it was five times greater than in

1830. Taking the record for the past half century, the above data indicates that the *pig iron output of 1890 was over thirty times that of 1840.*

Until 1840, all of this iron was made with charcoal and by far the greater portion of it was still produced with that fuel in 1850. The year 1855 was the first recorded in which the production of pig iron by the use of anthracite coal exceeded that made with charcoal, and in that same year, the amount of pig iron made with bituminous fuel was but eight per cent. of the total output. However, from 1855, anthracite kept in advance of the use of charcoal, and in 1860, the relative proportions of iron made with the different fuels were practically twice as much charcoal pig iron as coke iron, and twice as much anthracite iron as charcoal iron.

It was in 1864, that the United States first made 1,000,000 gross tons of pig iron, falling below that figure in 1865, but exceeding it in 1866. It would, therefore, be unfair to use the comparatively small output for 1865 as a gauge for subsequent growth therefor, and the production for twenty-five years, beginning with 1866, will be taken. We find from Table A, that the pig-iron industry advanced so rapidly that in six years, namely, 1872, more than double the amount of pig iron was produced than was made in 1866; in fourteen years (1880), the output was over treble that of 1866; in sixteen years (1882) it was almost four times the output of 1866; in twenty-one years (1887) it was over five times the output of 1866; in 1889, twenty-three years after, it was over six times the output of 1866, and in 1890, it was seven and five-eighths times the production of 1866.

This is truly a remarkable record of progress, and one which has never been duplicated in this or in any other country in a similar interval of time, and it may never be again, for if our output of pig iron increased seven and five-eighths times that of 1890 in the next twenty-four years, it would exceed 70,000,000 gross tons per annum, and equal in one year the aggregate production of pig iron for the past sixteen years.

TABLE A.

Annual Production of Pig Iron in the United States from 1866 to 1890.

	Recorded Number of Blast Furnaces.	*Number of Blast Furnaces Operating at Close of Year.*	*Production. Gross Tons of 2,240 Pounds*
1866,	—	—	***1,205,663***
1867,	—	—	1,305,023
1868,	—	—	1,431,250
1869,	—	—	1,711,287
1870,	—	—	1,665,179
1871,	—	—	1,706,793
1872,	612	—	2,548,713
1873,	657	410	2,560,963
1874,	693	365	2,401,262
1875,	713	293	2,023,733
1876,	712	***236***	1,868,961
1877,	**716**	270	2,066,594
1878,	692	265	2,301,215
1879,	697	388	2,741,853
1880,	701	446	3,835,191
1881,	**716**	**455**	4,144,254
1882,	687	417	4,623,323
1883,	683	307	4,595,510
1884,	669	***236***	4,097,868
1885,	591	276	4,044,526
1886,	577	331	5,683,329
1887,	583	339	6,417,148
1888,	589	332	6,489,738
1889,	570	344	7,603,642
1890,	***562***	311	**9,202,703**
A total output for twenty-five years of,			88,275,721

of which 56,902,041 tons were produced in the decade just closed. The maxima are in full-faced figures, the minima are in italics.

The pig iron produced in twenty-five years, if run in a solid mass, would cover one square mile, to a depth of sixteen feet.

DISTRIBUTION OF THE PRODUCT.

The statistics, collected from the manufacturers and published by the American Iron and Steel Association, show a total production of pig iron for the year 1890 of 10,307,028 net tons, or 9,202,703 gross tons, made in about 340 furnaces,

which were in operation for some portion of the year, although but 311 were active at the close of that year.

Of the total output:

6,388,147 gross tons, or about seventy per cent., was made by using bituminous coal.

2,186,411 gross tons, or twenty-four per cent., was made by using anthracite fuel in whole or in part, but only 249,-271 gross tons, or two per cent. of the total output, was smelted with anthracite coal alone.

628,145 gross tons, or six per cent., were made with charcoal as fuel. This is the largest amount of pig iron made by the United States in any one year by the use of this fuel, indicating improvement in this specialty, although the relative proportions of charcoal pig iron to the total is yearly diminishing.

Of the total production, 4,092,343 gross tons, or about forty-four per cent., were classed as Bessemer pig iron for the production of steel by the acid process.

The quantity of domestic spiegeleisen and ferro-manganese produced was 133,180 gross tons, or about one and a half per cent. of the total pig iron made in 1890. Practically all of this was used in steel manufacture.

At the close of 1890, the stocks of pig iron in makers' hands was 661,858 gross tons, or about seven per cent. of the total output.

Pennsylvania is credited with making 4,415,329 gross tons of pig iron, or nearly forty-eight per cent. of the total output for 1890, which still maintains this State in advance of all others.

Ohio ranks second with 1,240,330 gross tons, or thirteen per cent. of the total.

Alabama advanced last year to third in order of production, with an output of 816,911 gross tons, or nearly nine per cent. of the total, and

Illinois is fourth in importance, with a production of 701,106 gross tons, or seven and a half per cent. of the total.

Pennsylvania and Ohio together produced 5,655,659 gross tons, over sixty-one per cent. of the total output, and the aggregate of the four States, Pennsylvania, Ohio, Alabama

and Illinois, was 7,173,676, or nearly seventy-eight per cent. of the country's production of 1890.

COMPARISON WITH OTHER COUNTRIES.

The year 1890 is memorable as placing the United States in the lead, our output of pig iron being larger than that of any other nation, and our development may be emphasized by a comparative statement of the product by various countries within late years. (See Table B.)

An examination of the published tables of production of pig iron in this and other countries gives a close approximation, although not an absolute determination of the figures for the reason that it is not always possible to obtain contemporaneous data for the different countries. However, taking the most reliable records, we find that Great Britain first made 1,000,000 gross tons of pig iron per annum, in 1835, but the United States did not reach that figure until twenty-nine years later, namely, 1864, in which year Great Britain produced 4,750,000 tons. In 1866, the commencement of the period under discussion, the United States produced one-quarter of the annual output of Great Britain, and approximated the output of Germany and France. For four years following the United States, Germany and France kept well together in output. Great Britain produced 2,000,000 tons of pig iron in 1847, twelve years after it had made 1,000,000 tons; but the United States reached this figure in 1872, eight years after it had made 1,000,000 tons. It was then twenty-five years behind Great Britain. Germany made 2,000,000 tons in 1873, and France did not reach the production of 2,000,000 tons until 1882.

After an interval of seven years from the date that Great Britain reached 2,000,000 tons of pig iron per annum, namely, 1854, that nation made 3,000,000 tons, and the United States did not cover the same ground until an interval of eight years, namely, 1880, while it took Germany nine years, namely, to 1882, to make this product. France has never yet reached an annual product of 3,000,000 tons. After another interval of nine years, viz: 1854 to 1863,

Great Britain added another million to its output, making the production 4,000,000, but the United States covered this ground in one year, being at that time eighteen years behind Great Britain, and it took Germany five years to increase its output from 3,000,000 to 4,000,000 tons, reaching the latter figure in 1887. An interval of five years sufficed for Great Britain to reach a production of 5,000,000 tons, in 1868, and a similar interval brought the United States to the same output in 1886. Germany has never reached 5,000,000 tons. To pass the figure of 6,000,000 tons annual production, Great Britain required three years more, while the United States reached the same figure in one year, making the latter country sixteen years behind the former. In nine years for Great Britain and two years for the United States, each of these countries passed the production of 7,000,000 gross tons viz: in 1880 and 1889, respectively.

Great Britain's largest pig iron output was in 1882, when 8,586,680 gross tons were produced; the United States' maximum annual output was in 1890, viz: 9,202,703 gross tons. Germany's greatest output was in 1890, when 4,563,-025 metric tons were produced, and the largest output for France was 2,067,387 metric tons in 1883.

Of the other pig iron producing countries Austro-Hungary, Sweden, Belgium, Italy, Spain, Canada and Russia, none have produced in any one year 1,000,000 gross tons. The largest reported output from Austro-Hungary was in 1889, when 816,156 metric tons were produced; that of Sweden was in 1885, viz: 464,737 metric tons; the maximum output for Belgium was in 1889, when 832,226 metric tons were made, and in Russia the data have been so irregularly published as to make the figures uncertain, the report of 1888 of 612,000 metric tons being the largest published output. Spain produced 232,000 tons in 1888; Italy produced 12,265 tons in 1887, and Canada produced 18,191 tons in 1888.

The official statistical data for Great Britain covering the year 1890 show that 7,904,214 gross tons of pig iron were made. The United States therefore produced over sixteen per cent. more pig iron in 1890 than Great Britain.

TABLE B.

Annual Production of Pig Iron in Various Countries from 1866 to 1890 Inclusive.

	Gross Tons of 2,240 lbs.		Metric Tons of 2,204 lbs.	
Years.	*United States.*	*Great Britain.*	*Germany.*	*France.*
1866,	1,205,663	4,523,897	—	1,260,348
1867,	1,305,023	4,761,023	1,113,606	1,229,044
1868,	1,431,250	4,972,206	1,264,347	1,235,308
1869,	1,711,287	5,445,757	1,413,029	1,380,965
1870,	1,665,179	5,963,515	1,391,124	1,178,114
1871,	1,706,793	6,627,179	1,563,682	859,641
1872,	2,548,713	6,741,929	1,988,394	1,217,838
1873,	2,560,963	6,566,451	2,240,574	1,366,971
1874,	2,401,262	5,991,408	1,906,262	1,423,308
1875,	2,023,733	6,365,462	2,029,389	1,416,228
1876,	1,868,961	6,555,997	1,846,345	1,453,112
1877,	2,066,594	6,608,664	1,932,725	1,400,000
1878,	2,301,215	6,381,051	2,147,641	1,417,072
1879,	2,741,853	5,995,337	2,226,587	1,334,759
1880,	3,835,191	7,749,233	2,729,037	1,725,293
1881,	4,144,254	8,377,364	2,914,009	1,899,861
1882,	4,623,323	8,586,680	3,380,806	2,039,067
1883,	4,595,510	8,529,300	3,469,719	2,067,387
1884,	4,097,868	7,811,727	3,600,612	1,855,247
1885,	4,044,526	7,415,469	3,687,433	1,630,648
1886,	5,683,329	7,009,754	3,528,658	1,516,574
1887,	6,417,148	7,559,518	4,023,953	1,567,622
1888,	6,489,738	7,998,969	4,337,121	1,683,349
1889,	7,603,642	8,322,824	4,387,504	1,733,964
1890,	9,202,703	7,904,214	4,563,025	1,970,160

	Metric Tons of 2,204 Lbs.			
Years.	*Austro-Hungary.*	*Sweden.*	*Belgium.*	*Russia.*
1866,	319,709	—	—	—
1867,	361,038	—	423,069	—
1868,	425,071	—	435,754	—
1869,	450,567	285,065	534,319	—
1870,	452,244	293,438	565,234	354,032
1871,	476,627	293,277	609,230	353,710
1872,	531,850	334,788	655,565	393,065
1873,	594,980	339,685	607,373	378,387
1874,	545,742	332,154	532,790	374,355
1875,	504,347	343,551	540,473	420,484
1876,	450,933	344,834	490,508	—
1877,	409,000	336,370	470,488	—

TABLE B.—(*Continued.*)

Years.	Metric Tons of 2,204 Lbs.			
	Austro-Hungary.	*Sweden.*	*Belgium.*	*Russia.*
1878, ...	424,249	333,496	493,544	409,633
1879, ...	404,160	342,547	448,371	429,865
1880, ...	465,518	405,765	595,704	441,285
1881, ...	543,000	435,428	624,736	462,027
1882, ...	611,681	398,945	727,000	498,400
1883, ...	710,037	422,627	770,659	—
1884, ...	734,346	430,534	750,812	—
1885, ...	714,784	464,737	712,876	527,526
1886, ...	703,350	442,457	697,110	—
1887, ...	703,530	456,625	754,481	532,649
1888, ...	790,227	457,052	826,850	612,000
1889, ...	816,156	420,665	832,226	—
1890, ...	—	781,958	—	—

SOME OF THE AIDS TO AUGMENTED OUTPUT.

One of the factors which has aided in securing the output of 9,202,703 gross tons of pig iron in 1890 was that about seven per cent. of this never took the form of pig iron. The advances made in our large steel works demand economies in every department, and instead of running the metal from the blast furnaces into moulds in pig beds, allowing it to cool and then burning fuel to bring it again into a molten state, so as to feed it to converter or furnace, the iron is run from the blast furnace into ladles, carried on railway trucks and on these conveyed to the steel works for conversion into steel. Each year has shown an increase in the quantity of iron thus treated, and in the year 1890 fully 620,000 tons of molten iron was taken in this direct manner from blast furnaces to the steel converting plants.

When the practices of our great steel works are compared with the older methods, we understand why steel rails cost less than iron rails, or why steel plates undersell standard brands of plate iron. In these modern plants, the cold iron ore, fuel and flux enter the furnace and the cold or nearly cold finished rail is handled at the drill press or punch, but at no intermediate point in the manufacture is the metal produced cold or below a temperature for convenient manipulation in rolls or under hammers.

Inquiries addressed to our large steel plants indicate that the 620,000 gross tons of iron used direct in 1890; that is, carried in a molten state from the blast furnaces, will be much augmented; for one large mill using direct metal was idle on account of reconstruction one-half of 1890, and at another plant, the use of molten metal covered but two months of the year. We may also expect this practice to continue to expand in other special industries.

Another factor which has aided the development of the pig-iron industry is the association of the blast furnace and the chemical laboratory. The older empirical tests of bending a bar of iron to determine whether it was "cold short," "red short" or "neutral," or of noting the mere physical structure of fracture to recognize iron of foundry or mill grade, while serviceable still, have been supplemented by chemical analyses; and the percentage, or oftener the fractions of one per cent. of carbon, and the form in which it exists, of phosphorus, manganese, sulphur, silicon, etc., are now the generally accepted criterions of merit.

But the chemical laboratory would fulfil but a part of its functions without a practical and technical application of the results there obtained, and to the intelligent, progressive energy and conscientious attention to details which have characterized many of our blast furnace managers, the people of the United States are largely indebted for the position which our country has taken as a producer of pig iron.

As a rule, the efforts of this class (practically a creation to meet peculiar business requirements), are scarcely appreciated, for it is not only the manager, who, with well-equipped blast furnace and rich ores, makes a brilliant record, but also he, who with inefficient appliances, lean or refractory ores and varying mixtures, accomplishes what a few years ago would have been considered impossible, who should share in the credit of the good work accomplished.

The structural features and the mechanical appliances introduced have done much to advance the possibilities of pig iron production, and have given the means of constructing, operating and successfully handling the product of our large blast furnaces, while permitting the smaller plants to

work with greater economy. With the appliances in use at what were modern furnaces a quarter of a century ago, it would be practically impossible to handle the material supplied to, and the metal and slag flowing from, some of the larger blast furnace plants of to-day.

Another factor of importance in securing the present position of the United States as a pig iron producer is the study which the consumers have given to the character and qualities of the pig iron which they use. While this investigation has not been as general as is desired, outside of the steel works; there is a large share of credit due to the users of pig iron for the time and money expended in experimenting upon various grades and compositions of iron to secure certain results. Evidences of this are found in the American chilled car wheel, which, to meet the severe requirements of the service, must have a soft, tough hub, a hard, smooth tread, and yet be placed on the market at a cost which seems ridiculously low. One of our local manufacturers has published a record of tests of 10,000 chilled iron car wheels, made by a testing bureau, which shows that 8,690 did not vary one-twenty-fourth of an inch in diameter as they came from the chills, and, at that, an average of fifty blows of a weight of 140 pounds, falling twelve feet, was required to break 105 of these wheels (the number tested). The firm states that in none of the wheels was there a variation in depth of chill of more than one-eighth of an inch, and not a single wheel was rejected from the whole number offered for inspection because of any chill-cracks, blow-holes, or other imperfections of workmanship or material, and the metal in all the wheels broken, was found to be of a good, soft, open, gray in the plate and free from slag or dirt. The tread of every wheel was practically smooth, and not one needed to be ground, or in any other way made smooth or true.

Such an achievement is not the result of any "rule of thumb procedure;" it is the outcome of experimental and exhaustive laboratory and foundry tests, coupled with a patient study of mechanical appliances. The above instance is only given as one of many. It has been but a few years

since attention was directed to the remarkable influence which a small percentage of aluminum exerted upon cast iron, one-half of one per cent. being sufficient to make a material change in the physical features of the cast metal. The large amount of speigeleisen and ferro-manganese which has been produced and used in this country, makes familiar the influence of manganese upon iron, and has caused it to be studied thoroughly. A series of very careful tests and examinations as to the influence of silicon upon iron, and the manufacture of ferro-silicon has also attracted attention, and lately we have learned from official tests, of the influence exerted upon iron for armor plate by a small percentage of nickel.

All of this goes to indicate that attention has been devoted to the chemical and mechanical properties of iron by those who use the metal, thus increasing the demand.

It would be ungenerous, in noting some of the causes which encouraged the marvellous development of our pig-iron industry, to omit mention of the assistance rendered by organizations and by the technical and trade press. The generous interchange of experiences brought about by social acquaintance, the reading and discussion of papers at the meetings of technical, engineering and trade organizations, have been of great assistance to many who control our blast furnaces. The liberal publication of technical and commercial data has, through the medium of a number of special publications, lifted many out of ruts which they would naturally follow in practically isolated locations without the knowledge of what was accomplished and how results were attained elsewhere. The collection and prompt publication of statistical information has been of marked service, and much of the data presented in this lecture is proof of the value which the manufacturers of pig iron place on this feature. Without their cordial coöperation and confidence, this data would not be obtainable, and with their active interest, the publication within four weeks of the complete statistics of pig iron production for the year 1890 is most creditable to Mr. Swank and his associates in the American Iron and Steel Association. The figures

represent returns from the 562 blast furnaces of the United States, now considered as active; they give the number of furnaces in blast or idle, with the amounts of iron made by different fuels and of special character in each producing State, and in some instances, of districts in a State, and the stock of iron on hand is also given in the same detail.

THE BLAST FURNACES.

The blast furnace (a structure either built of stone masonry or excavated out of the solid rock), about 30 feet high, having a bosh of 7 or 8 feet in diameter, had grown in 1866 to a more pretentious structure, where a height of 60 feet and a bosh diameter of 16 to 17 feet was attained, but in a majority of cases, the masonry structure was maintained, although brick displaced the stone to some extent, and the boilers and hot blast stoves were often erected upon heavy and expensive arches or carried on side hills supported by massive retaining walls. The output of twenty to thirty tons per week had grown to 150 or 200 tons in 1866.

The blast furnace of to-day, producing five times the amount of iron, costs little more than the furnace of twenty-five years ago, and is a more convenient, more shapely and a better equipped plant.

Probably no better illustration of the development of the blast furnace can be offered than the following memoranda concerning the largest plant in Pennsylvania, viz: that of the Edgar Thomson Steel Works.

This plant consists of nine blast furnaces, which can produce together over 2,000 tons of pig iron daily, and lately have averaged a total output of between 1,500 and 1,600 tons per day. One of the furnaces, which is chiefly used for producing spiegeleisen and ferro-manganese, is 65 feet high with a bosh diameter of 15 feet; two of them are 80 feet high with boshes 20 feet in diameter; two are 80 feet high with boshes 22 feet in diameter; two are 90 feet high, with boshes 22 feet in diameter, and two are 80 feet high, with boshes 23 feet in diameter. Twenty-six blowing engines supply blast for this group of furnaces. All of the engines have blast cylinders, 7 feet in diameter, and are of 4 and 5

feet stroke of piston. One hundred and sixteen boilers furnish steam to drive the blowing engines, the pumps and hoisting appliances, and twenty-four pumps are in constant use, furnishing water. Thirty-three hot blast stoves heat the air supplied.

One of these furnaces has reached the remarkable output, for a single day, of 457 gross tons of iron, in a week one furnace stack has made 2,462 gross tons, and in a month one stack produced 10,164 gross tons; that is, in one month, one of these furnaces produced fully as much iron as twenty-five years ago would have been turned out in a year from the best and largest of the American blast furnaces. This is not due alone to the equipment nor even to the equipment and management, unless in the management is included the appreciation by the owners of the value of using richer ores and of paying for the preparation of the ore used, so as to increase the percentage of iron.

The number of blast furnaces in the United States is now less than has been reported at any time for the past twenty years. (See Table A.) Notwithstanding the new plants added, the active list of 1890 numbers eight less than that of 1889. The increased output of pig iron is due to larger average dimensions of the furnaces, better equipment and improved management.

By reference to the table of the total number of furnaces, and those in blast at the close of various years (see Table A), it is evident that the largest number of furnaces in any year was 1877 and 1881, when 716 were on the active list. Since that time there has been a gradual decrease in the number, owing to the older and smaller furnaces which had no possible future, dropping out. The largest number in blast at one time was in 1881, when there were 455; the smallest number was in 1876 and 1884, when 236 only were in operation.

We have no reason to anticipate a serious break in our growth in population, and as we increase in numbers, more iron will be necessary. If our general prosperity continues, the augmented wealth of the nation should encourage a greater production of pig iron per capita.

A considerable portion of our country is inadequately supplied with transportation facilities, the extension of railroads will build up new towns, towns will grow into cities, each commanding an increase in the pig iron product, both for railway connections and local requirements.

CENSUS FIGURES.

The development of the pig-iron industry, as indicated by census returns for the years 1870, 1880 and 1890, is as follows: 9,579,779 net tons are reported by Dr. Wm. M. Sweet, special agent in charge of the iron statistics for the eleventh census, as the output for the United States for the year ending June 30, 1890.* This is equivalent to 8,553,374 gross tons. It shows that from 1880 to 1890, the production of pig iron increased 153 per cent., while from 1870 to 1880, the production was augmented eighty-five per cent.

The general distribution of this production in the three census years, 1870, 1880 and 1890, is exhibited by Table C.

TABLE C.

Production of Pig Iron in the United States according to Census Returns.

	Tons of 2,000 Lbs.		
Districts.	*Year Ended May 31, 1870.*	*Year Ended May 31, 1880.*	*Year Ended June 30, 1890.*
New England States, . . .	34,471	30,957	33,781
Middle States, ...	1,311,649	2,401,093	5,216,591
Southern States, ...	184,540	350,436	1,780,909
Western States, ...	522,161	995,335	2,522,351
Far Western States, . . .	—	3,200	26,147
Total, ...	2,052,821	3,781,021	9,579,779

PROSPECTIVE DEVELOPMENT.

Having discussed the past and considered the present, attention may be devoted to the future of the pig-iron industry, and the question naturally arises will this development continue in the same ratio; that is, will the next twenty-five years show as marked growth, or what will

* The apparent discrepancy between the figures of Messrs. Swank and Sweet is due to the different intervals covered by their reports.

that growth be relatively to the twenty-five years past, which are especially covered in this lecture. It has been shown that the output of 1890 was seven and five-eighths times that of 1866, and that to make the same advance in the next one-quarter of a century, it would demand a production in 1915 of over 70,000,000 gross tons of pig iron. This we do not expect to attain. If we take the last two decades, we find that our pig iron output has increased over five and one-half times, and this rate would make the production in 1910, two decades hence, exceed 50,000,000 gross tons. Neither is it presumed that we will reach this figure. In the last decade, we have augmented the output nearly two and one-half times; a similar increase in the coming decade would make the production of pig iron in 1900 22,000,000 gross tons, which would also represent a large rate of increase. It must be remembered that a portion of the later development has been abnormal, and is not to be credited to augmented consumption. Some of the late increased production solely of pig iron is due to the restrictions of importation, which will hardly be again removed, unless by legislation, which would greatly damage the industry; and lately, considerable development has been associated with real estate speculative schemes, which will be apt to exert a restricting influence in the near future. But while it is not probable that either of the figures above-mentioned will be reached in the intervals of time indicated, if political action does not disturb the industry, or if labor troubles do not seriously interfere with developments, there seems no reason for expecting that the pig-iron industry will remain dormant, but we may rather look for a nearly steady growth which, at the expiration of twenty-five years, will probably make the annual requirements of the United States, in pig iron or its equivalent, amount to between 20,000,000 and 25,000,000 gross tons.

Fortunately, we can only surmise as to the future, but these figures are the result of a careful study of statistics, taken in connection with an intimate knowledge of the present state of development and a personal acquaintance with the possibilities of various portions of the country.

There will be times of depression followed by others of unusual activity, but we may confidently look forward to a material advancement, perhaps greater than I estimate, but certainly much more pronounced than was believed possible ten years ago.

[*To be continued.*]

LOUIS H. SPELLIER.

The subject of this memoir was born in Hanover, Germany, on January 6, 1841, and died in Philadelphia, August 22, 1891, in his fifty-first year.

He received a good technical education in the schools of his native city, and afterwards learned the trade of watch- and clock-making with his father, Frederick Spellier. Shortly after attaining his majority, he came to this country, locating first at Doylestown, in Pennsylvania, where he practised his handicraft until the year 1880, when he removed to Philadelphia. It was whilst living at Doylestown that he applied his leisure time to the study of electric clocks and time-telegraphy, in which field of invention he afterwards achieved a distinguished position.

The record of his inventions is given in the following:

In 1874, he exhibited, at the exhibition of the Franklin Institute, a large clock of his own handiwork, to which he had applied an improved escapement. For this he was awarded a silver medal.

The same invention was recognized by the judges of the Centennial Exhibition two years later, by the award of a medal.

Encouraged by these recognitions of his ingenuity, he continued to work assiduously in his chosen field, and shortly thereafter developed a system of time-telegraphy for which he secured, at intervals, letters-patent of the United States, covering the following subjects, viz: an electric motor for clocks, a sparkless circuit-breaker and a contact-maker for electric clocks. These patented improve-

ments completed an electric clock, or system of electric time-telegraphy, the merits of which were fully recognized in the leading technical journals of the United States, France, Germany and England, and in the recent works on the subject, in several of which Mr. Spellier's inventions are deemed of sufficient importance to be described as constituting a distinctly original system.

The Franklin Institute, through its Committee on Science and the Arts, testified to the value of Mr. Spellier's inventions by awarding him the Elliott Cresson Medal, in 1881, for his improved escapement; and in 1884, on the recommendation of the same committee, he received from the Board of City Trusts the John Scott Legacy Medal and Premium for his electric-clock system.

The Spellier patents were lately acquired by a Philadelphia company, and the system has been for several years in service in this city.

Mr. Spellier visited his native place last year, chiefly for the benefit of his health, which had become impaired by constant and close application for years. Upon his return, he applied himself to perfecting the invention of a self-winding electric clock, of which he had completed a second model only a few weeks prior to his death, and had made application for a patent. Those who have had the opportunity of inspecting this last work of Mr. Spellier, speak highly of its merits.

Mr. Spellier's ability as an expert in his special branch was recognized by the publishers of the new edition of the *Iconographic Encyclopædia*, in the sixth volume of which appears an admirable article from his pen on "Time Telegraphs."

Mr. Spellier was elected a member of the Franklin Institute in 1874, and was always warmly interested in its work. He was a regular attendant of its meetings, and served for a number of years upon the Committee on Science and the Arts, of which he was a member at the time of his death.

Personally, Mr. Spellier was courteous and unassuming in manner and the possessor of a cheerful, kindly and amiable disposition, which gained for him the warm esteem of

his associates and fellow-members. His death, following a very brief illness, was entirely unexpected.

WM. H. WAHL, *Chairman.*
ARTHUR BEARDSLEY.
W. M. MCALLISTER.
EDWARD F. MOODY.

PROCEEDINGS

OF THE

CHEMICAL SECTION

OF THE

FRANKLIN INSTITUTE.

[*Stated meeting, held at the Institute, Tuesday, October 20, 1891.*]

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, October 20, 1891.

Dr. W. H. WAHL, President, in the chair.

Mr. W. N. Allen, No. 2 Chestnut Street, Philadelphia, was elected a member of the section.

Upon motion it was voted that the section cause to be printed a form of letter to be used by the Secretary for the purpose of informing newly-elected members of their admission to the section.

A letter from Mr. Otto Lüthy was read, announcing that illness prevented him from attending the meeting. The paper which was to have been presented by him was therefore deferred to a future meeting.

Dr. Bruno Terne read a valuable and highly interesting paper on "The Utilization of the Bye-products of the Coke Industry."

The paper was illustrated fully by lantern projections. The paper called forth an extended discussion, in which Dr. Jayne, Mr. Henry Bower, the author and the President took part. The paper and discussion thereon were referred for publication in the *Journal.*

Dr. E. F. Smith presented a paper by himself and Mr. Hough, of the University of Pennsylvania, on (I)—"The Iodation of *p*-Bromobenzoic Acid," and (II)—"Salts of *p*-Bromo-*m*-nitrobenzoic Acid." It was read by title and referred for publication in the *Journal.*

Adjourned. WM. C. DAY, *Secretary.*

NOTES ON SOME CASES OF DRINKING WATER AND DISEASE.

By William P. Mason.

[*Read at the stated meeting of the Chemical Section, held May 19, 1891.*]

Drinking water and disease, upon which I am expected to speak to-night, is a question of such exceeding breadth, that so considerable a title certainly outweighs the small amount of matter capable of being placed within the compass of a short paper. I therefore beg to present only some few facts which have come within my own experience, and certain other matter bearing directly thereupon.

In that most excellent treatise upon "Water Supplies and Inland Waters," recently issued by the Massachusetts State Board of Health, waters are classified into "normal" and "polluted," the former being such as are free from addition, directly or indirectly, of either sewage or industrial waste.

The relation of "normal" waters as a class, to sanitary science, constitutes a subject by itself, and one by no means completely understood, as is instanced by the doubt we entertain of the effect of fresh water algæ upon our city supplies. However objectionable such growths may be from an æsthetic point of view, owing to the disagreeable odors generated, we must nevertheless confess to much ignorance as to their pathogenic importance. It has been my fortune to meet with but few cases of illness traceable to normal waters, and in all such instances the patients suffered from a mild and transient form of diarrhœa, caused by water from a low-lying small lake or pond, surrounded by low wooded banks. Of course, as in the experience of other water analysts, the commonly reported cases of algæ have been met with, but no material has so far been secured whereby disease could be traced to their presence. We will all look with interest to the results of the investigation now

being undertaken by the American Water Works Association, and we hope for further light upon this point.

As concerning the second division referred to above, namely, polluted waters, permit me, for the moment, to make a further subdivision, and consider the admission of sewage from pathological sources, as distinct from that derived from healthy persons. I ask for the distinction because without it, it would often be hard to account for the long-continued immunity from disease, enjoyed by people who habitually make use of waters which are unquestionably grossly polluted.

How often do the cases of contaminated city wells illustrate this point, and how frequently is the chemist met by this refuting "test of experience," when he knows not only from the results of his own analysis, but from personal inspection of the vaults in the neighborhood, that such wells drain sources of outrageous filth. In view of the over-taxed purifying powers of the intervening soil, there is but one way out of the dilemma, and that is that sewage from pathologic sources has as yet not chanced to reach these wells, or else that such persons as swallow specific germs do not, at the time, furnish suitable ground to grow the seed which disease has planted.

You will remember that Emmerich made very light of the objections raised against ingestion of sewage material, and even went so far as to personally consume no inconsiderable quantity of it daily, and induced some students of his to do likewise. In contrast with his physiological results, permit me to relate a somewhat interesting case with which I was connected.

Rain-water, from a cistern of the filtering type, situated upon carefully managed property, had been in use for some years. Suddenly, with little warning, the entire household, one person excepted, were taken ill. The symptoms varied from intense nausea to great, if not dangerous, prostration. The one person who escaped illness was the only one who did not use the water. Among those attacked were several children.

Upon investigation, both cistern lining and private sewer

were found defective, and permitting of more or less direct communication. Up to the time of the outbreak none of the household had suffered from diarrhœa or kindred troubles, nor could I obtain any history of recent disease of any kind. The children attacked were on a short visit only. The point to be emphasized in this case is that the sewage which caused the trouble was "normal." Although I secured an analysis of the water at the time illness was produced, it is to be regretted that no previous analyses were on record, which might have established some relation between the figures of the analysis and the "poisoning point" of the water.

The serious evils lurking in water containing sewage derived from sources of disease, are too well-known to need enlarging upon here, and the dangers to be dreaded from the improper disposal of city drainage, is one of the widely-talked-of topics of the day.

Much has been said and written upon the ability of sewage-laden streams to purify themselves, and authorities of great weight are to be found on either side. Some time since a series of analyses were undertaken, as you will remember, by Dr. Long, of Chicago, upon the dilute sewage contained in the Illinois and Michigan Canal. It is to be noted that this canal receives its supply of water (or rather dilute sewage) at Bridgeport, where the pumps deliver to it the filthy water of the Chicago River, contaminated with a great portion of the sewage of Chicago. From Bridgeport the water "flows along the level to Lockport, twenty-nine miles below, requiring about a day for its passage." It receives no dilution on the way and is frequently agitated by passing boats. "After passing Lockport the water descends to Joliet through four locks, and falls over a dam seven feet in height to point of collection. There is a fall of 58·2 feet in a distance of four miles, and no dilution takes place on the way." The experiments with this canal water have been both numerous and thorough, and judging from the mean results there is good ground for the statement that very considerable self-purification takes place during the flow of thirty-three miles.

I have long been of the opinion, however, that what may be very true for dilute sewage, does not hold good as we approach the limit of potable water.

In other words, so far as purification of a water by the natural processes of oxidation is concerned, I believe that the rate of such purification varies directly as the amount of sewage contamination. Given a stream with a certain amount of pollution, the per cent. of such pollution which must disappear per mile of flow, will continually decrease as the stream flows on. To return to Dr. Long's figures. The analyses as given by him are as follows, in parts per million:

At Bridgeport:

	Free Am.	*Albu. Am.*	*Oxygen Consumed.*
June 26,	2·6	0·64	12·0
July 3,	2·7	0·52	6·8
17,	25·0	1·50	22·1
24,	5·5	0·37	12·6
31,	23·0	1·76	23·2
Aug. 7,	26·0	1·50	16·8
14,	29·0	1·64	32·0
21,	27·2	1·50	28·0
28,	29·2	1·90	35·2

At Lockport:

June 26,	2·8	0·56	11·36
July 3,	2·4	0·42	7·20
17,	10·2	0·72	12·80
24,	9·2	0·47	14·80
31,	11·0	0·72	10·70
Aug. 7,	12·0	0·48	9·60
14,	15·2	0·88	9·76
21,	15·0	0·84	10.80
28,	13·0	0·88	12·40

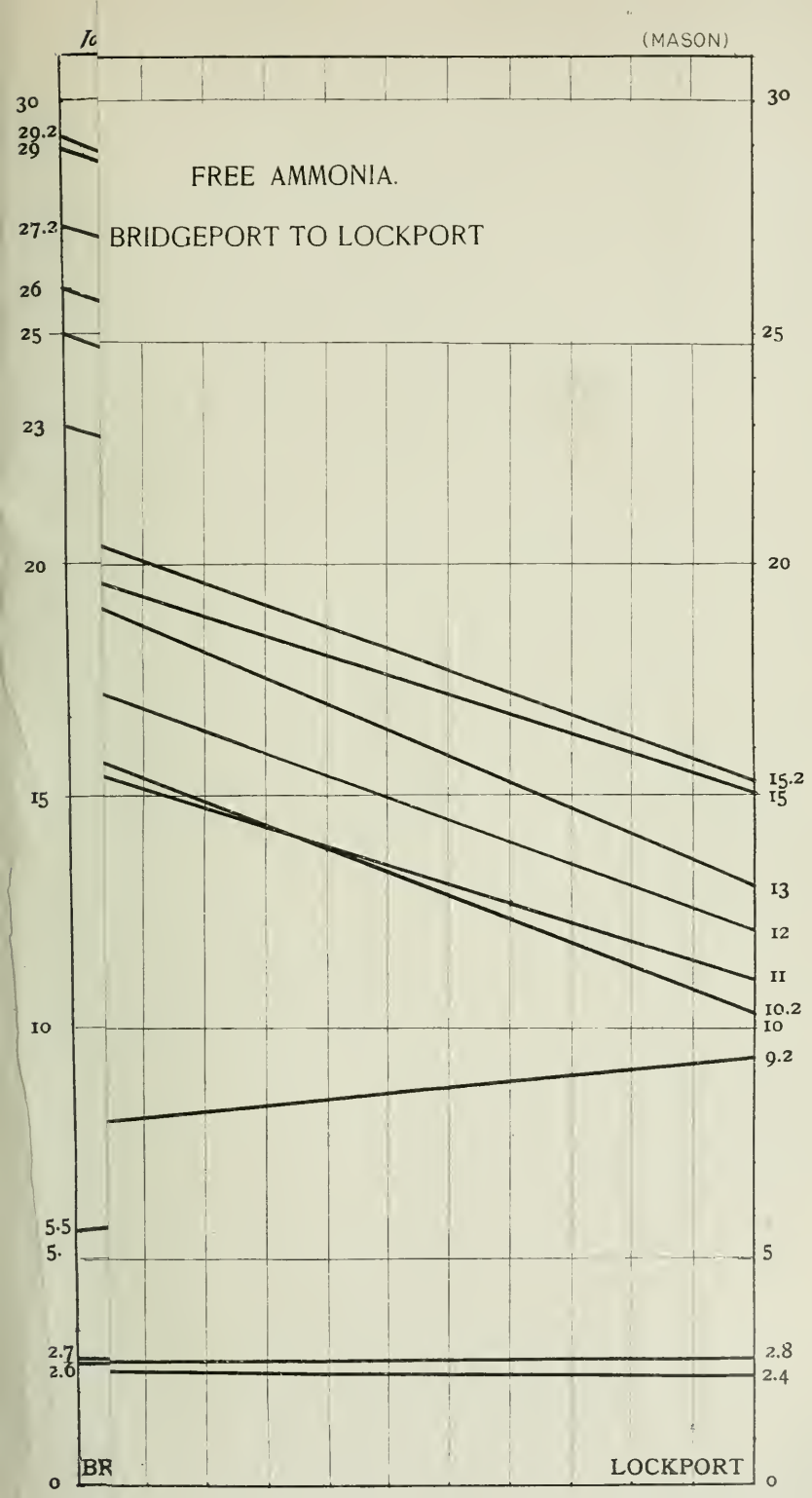
At Joliet:

June 26,	1·7	0·46	7·36
July 3,	1·8	0·46	9·76
17,	13·0	0·44	14·50
31,	9·2	0·44	5·68
Aug. 7,	7·5	0·42	5·84
14,	9·8	0·46	5·76
21,	9·0	0·11	0·52
28,	8·0	0·32	6·80

Plating these in graphic form they assume the shape shown on the accompanying charts. The change in lake level at various dates, together with other disturbing influences, caused comparatively clean water to reach the pumps at times, and we, therefore, are furnished with data governing the purification of several variously contaminated waters, while flowing under constant conditions.

It will be noticed that the rate of purification per mile for the more grossly contaminated samples, is much greater than that for those comparatively pure. Thus, during the flow from Bridgeport to Lockport the sample of July 3d loses 11·2 per cent. of its free ammonia and 19·3 per cent. of its albuminoid ammonia, while the sample of August 28th loses 55·5 per cent. free ammonia and 53·7 per cent. albuminoid ammonia while flowing the same distance.

Even the best of these waters of the Illinois and Michigan Canal is very far from being potable, and we may consequently look for still further reduction in the purification rate as we near the potable limit. My experience with the waters of large streams contaminated with city sewage, for instance, the Hudson River, is that self-purification is exceedingly slow. Having been employed by the Board of Health to examine into the quality of the Hudson River water opposite Albany (which water, taken directly from the side of the wharf, constitutes the present city supply), I made a very thorough examination of that section of the river. Permit me to digress here for a moment to state that it is my conviction that analyses of water from any one spot in a large stream, are valueless for the purpose of determining the continued presence of up-stream contamination. The dilution is commonly much too great to permit the sewage revealing itself. The Albany case is one in point. In order to determine whether Troy sewage, entering six miles above, was felt at the Albany intake, the river water was first sampled above Troy and then below the Troy sewer outfalls, where no one would hesitate to say that contamination was serious. A difference was noted between the two results which was undoubtedly caused by the influx of the Troy and Mohawk River sewage.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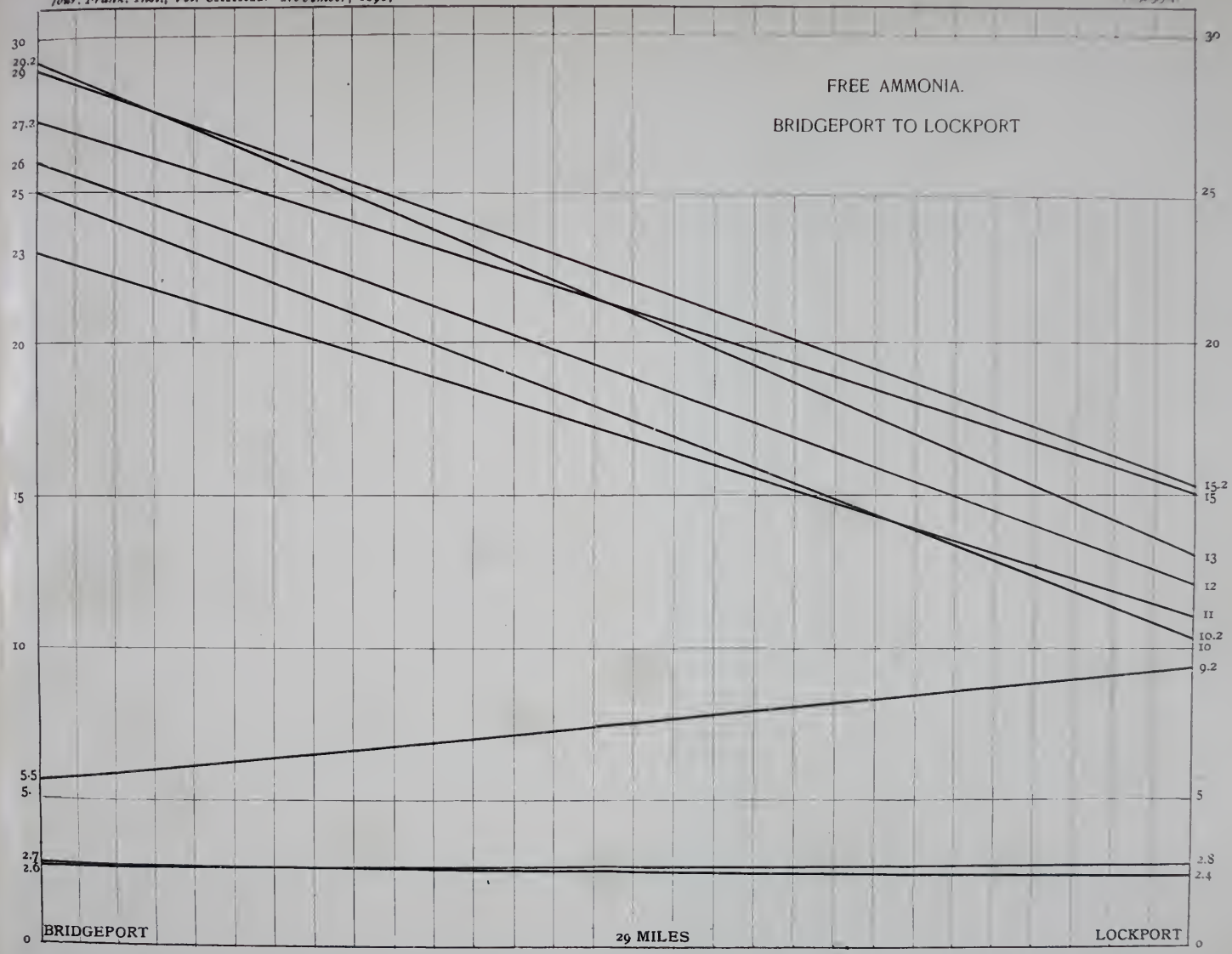
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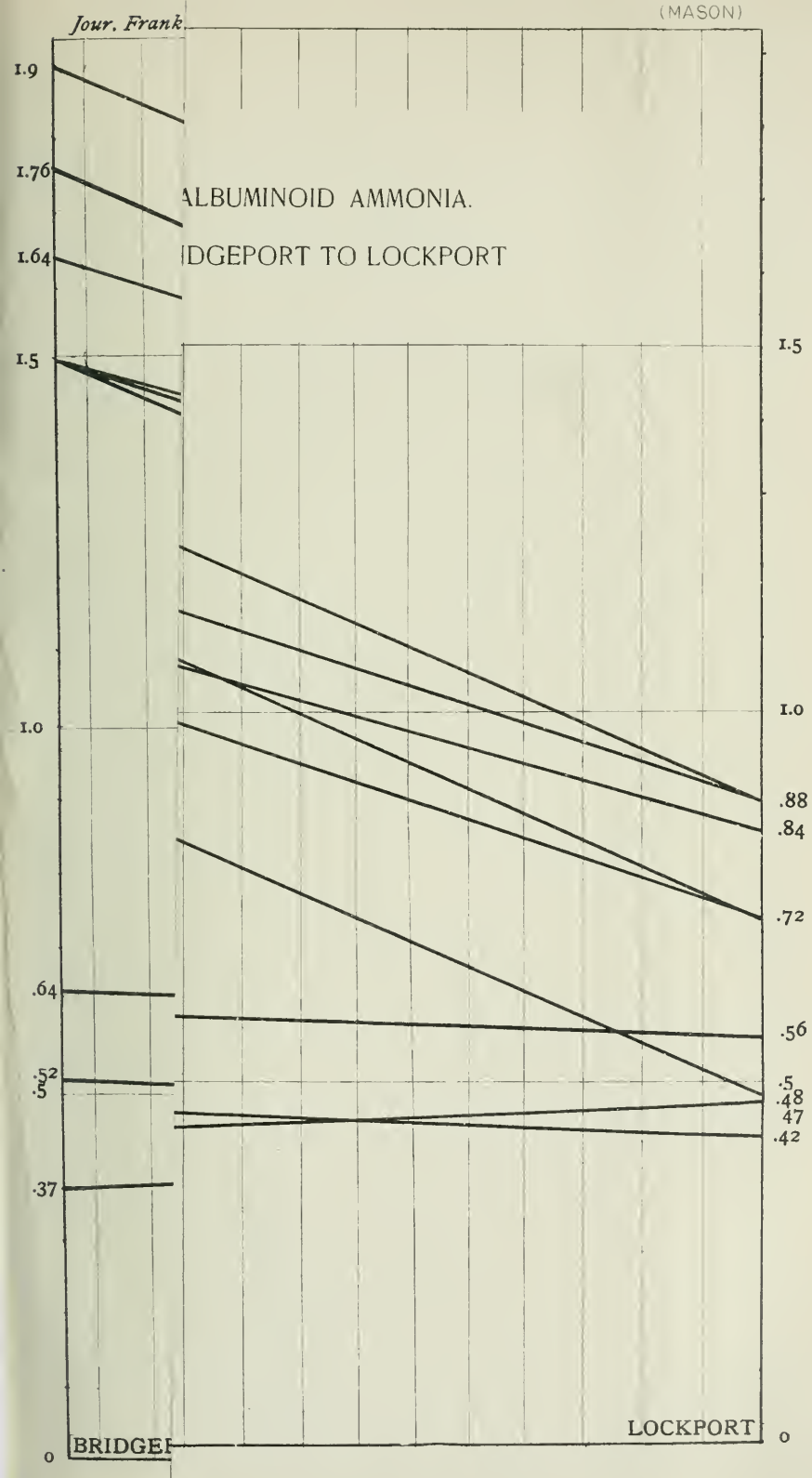
ALBUMINOID AMMONIA.
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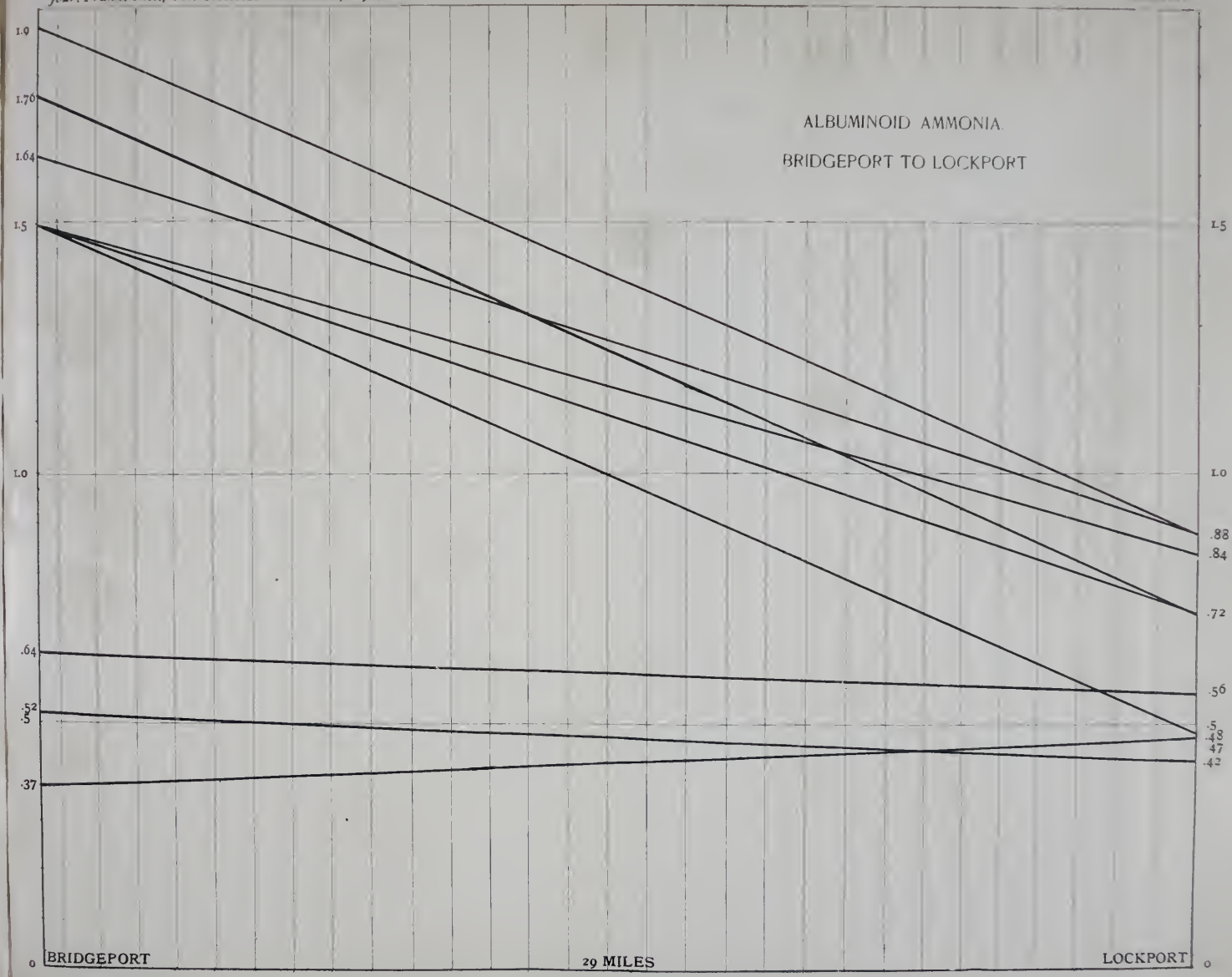
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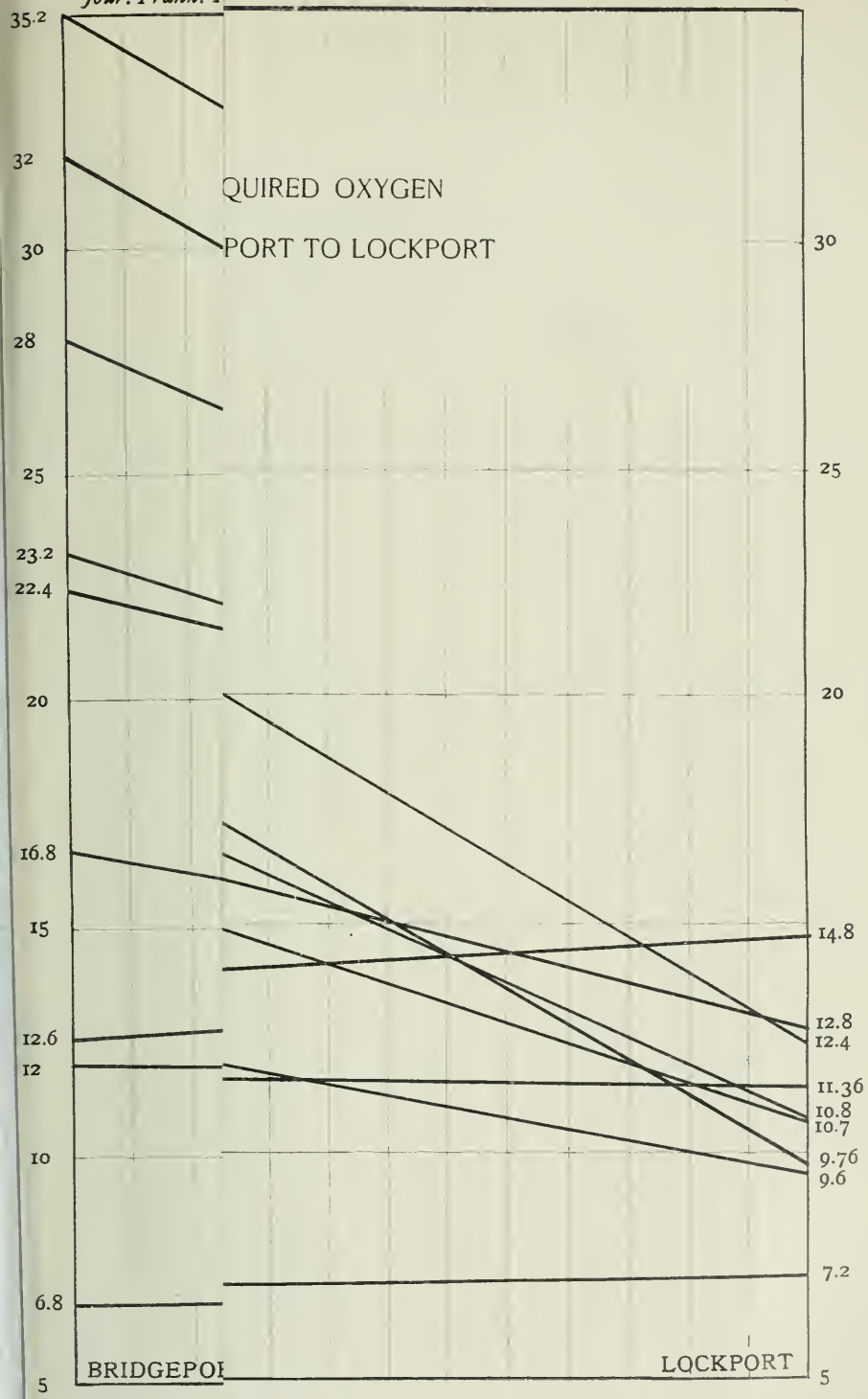
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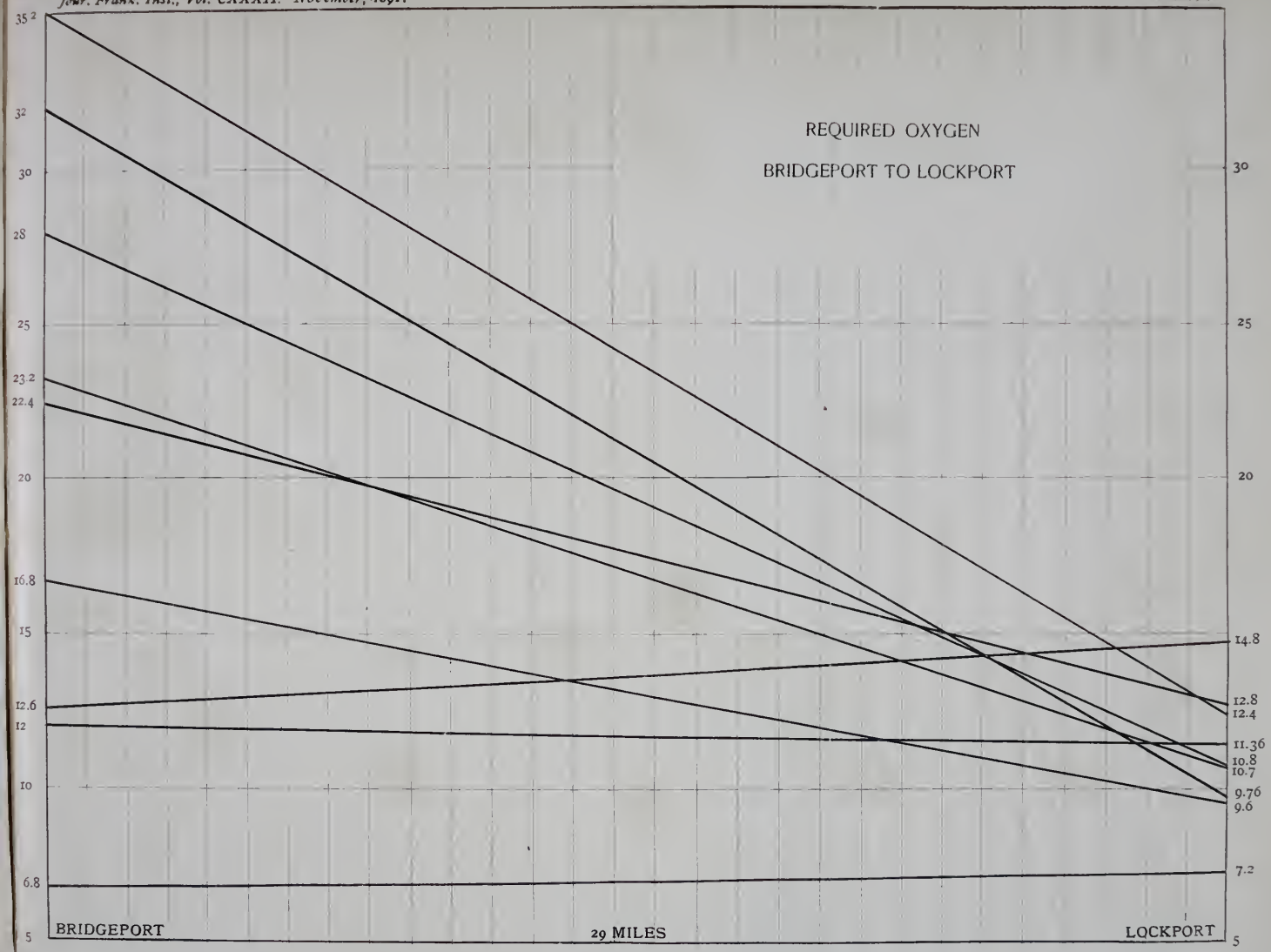
REQUIRED OXYGEN
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BRIDGEPORT
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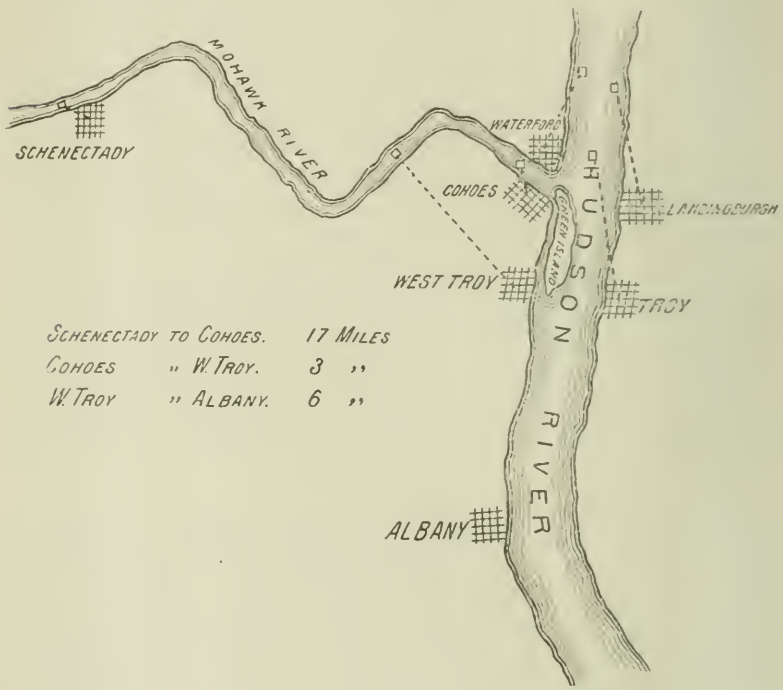
Upon continuing the collection of samples, every mile there were obtained analytical results which showed that the difference between the waters above and below Troy was largely maintained when Albany was reached. On the strength of the maintenance of this difference, rather than upon the results of any separate analysis, I pronounced against the Albany water supply as being contaminated with sewage from up-river sources. Directly relating to what has been referred to, let me finally ask your attention to a few facts of recent history, bearing upon the late outbreak of typhoid fever in Albany and vicinity.

By a glance at the accompanying chart, the locations will be observed of the several cities and towns situated at and near the junction of the Mohawk and Hudson Rivers. Every one of these centres of population drains into the river on whose banks it is situated, and each of them takes the greater portion of its water supply directly from such river by means of pumps. Mark this difference, however, Waterford, Lansingburgh and Troy are supplied with Hudson River water above the junction with the Mohawk, and the village of Green Island obtains its water from wells driven into its sandy soil. It is therefore supplied with filtered Hudson River water, while all the others use Mohawk or Mohawk-Hudson water.

The several intakes are indicated on the chart by squares. Under date of April 11, 1891, the Health Officer of Schenectady writes me: "The marked increase in typhoid fever began in July, 1890, and has just let up. We have had about 300 cases. Doctors have not been particular in reporting them, and we have had so many cases of anomalous fevers, that diagnosis is questionable. Seventy deaths have been reported." Permit me to say that it has not been the rule during this epidemic, for physicians to do their whole duty in reporting cases. I know of one instance in which only two or three cases were reported out of twenty-five. Schenectady is a very old town (of 20,000 inhabitants), and its sewerage system is doubtless none of the best, but its drainage eventually reaches the Mohawk and is carried onward with the current.

The following information was obtained from Dr. Leo, Health Officer of Cohoes, and from Dr. Peltier, his predecessor. Population of Cohoes is 22,000.

The epidemic of typhoid began in Cohoes about the end of October, 1890, and ceased about the middle of the following March. Altogether there were about 1,000 cases. The cases were mild in character, resulting in very few deaths. Cohoes takes its entire water supply from the Mohawk and



returns its sewage into the same river. Boiling of water for drinking purposes was recommended, and no typhoid developed among families who followed the recommendation, except in those instances where members of such families drank unboiled water while at work away from home. A portion of the city is owned by the great Harmony Knitting Mills, and is built up with tenements for their employés, of which there are many hundreds. These tenements are

kept in excellent repair and the plumbing is the best in the city, but extends to kitchen sinks and drains only. No water-closets are employed, as each house is furnished with privy vault in back yard. Typhoid was especially bad in this quarter. The Cohoes Health Officer has professional occasion to visit in Waterford (population 5,400) and in Lansingburgh (population 10,000), which towns are connected with Cohoes by bridges. He reports that hardly a case existed in either of those towns, and it is to be noted that they draw water from the upper Hudson above the Mohawk junction.

West Troy is situated on the Hudson and sewers therein, but by aid of the chart it will be noticed that its water supply comes from the Mohawk some distance above Cohoes. Its population is 13,000. The following information was obtained from Dr. McNaughton, health officer:

Epidemic of typhoid began the last of November. At meeting of Health Board, about December 15th, fifty cases were reported. Of these, forty-two had used Mohawk water, the remainder well water. On December 20th, the Mohawk supply was shut off and arrangements made with the town of Green Island (which village, by the way, had no fever) to use a portion of its supply of filtered Hudson water. One week thereafter the weekly report of cases showed fifteen, and the second week thereafter but one case was reported. The Green Island supply was used one month. Upon returning to the Mohawk supply in the middle of January, a slight increase in typhoid was observed. Total number of cases exceeded 100. The fever, as in other places, was very mild, resulting in ten deaths. Troy is situated directly opposite West Troy. Its population is 60,000. Its water supply comes partly from lakes back in the hills, partly from the Hudson above the Mohawk junction.

There have been very few cases of typhoid in Troy during the past year, and of those few a large percentage were imported from Schenectady and West Troy.

Troy dumps 8,000,000 gallons of sewage into the Hudson daily.

Six miles below Troy is the city of Albany; population, 100,000. Albany takes its water through an intake in the side of the wharf, directly in front of the city. Not only does sewage from the upper Hudson and Mohawk flow towards it, but during flood tide and south wind, the return of its own sewage from the sewer outfalls below has been proven by the floating of buoys.

The typhoid epidemic began in Albany the last of December, 1890. The disease was very mild in character, resulting in sixty-two deaths during the months of January, February and March, 1891. The total number of typhoid cases reported during the same period is 411, but this figure I have reason to know is absolutely unreliable. Albany experienced a very serious epidemic during the past winter, and the alarm was widespread, of that there can be no question. A small portion of the city receives its water supply from an inland gravity source. Typhoid was not nearly so plenty in that section, only eighteen cases being reported to the end of March.

An attempt has been made to fix the Albany epidemic upon the bad sanitary conditions of the house drains, whereby sewer air was admitted into the dwellings. In one section visited, sixty-five houses out of seventy-five possessed drains which leaked sewer air, and at the Albany Penitentiary, where the drainage system is perfect and where the inmates drink unpurified river water, there occurred no case of typhoid.

Faulty drainage, permitting the inhalation of sewer air, doubtless would induce a condition of the system favorable to the propagation of the typhoid germ should it be introduced, but it must be remembered that Troy has sanitary surroundings and appliances fully as undesirable as Albany, yet no epidemic occurred there.

Possibly the excellent sanitation at the penitentiary maintained the inmates in a condition of health such as to resist the planting of the disease.

Finally, as I am informed by Dr. Craig, of Albany, at Van Wie's Point, four miles below Albany, the laborers employed in cutting ice for the great ice-houses, had typhoid

fever break out among them during January. They used river water for drinking purposes.

To conclude, typhoid germs have been carefully looked for in the water and have not been found. But in view of the relative volumes of a city water supply and a sample for bacteriological examination, such a result does not appear surprising. There are those who hold that this outbreak of typhoid fever is to be explained in some other way than by attributing it to a contaminated water supply, but when we bear in mind that, out of this group of closely situated cities and towns, all of those which used the Mohawk-Hudson water contracted the fever, and that all those which did not use such water escaped, there is much food for thought.

RENSSELAER POLYTECHNIC INSTITUTE,
TROY, N. Y., May 18, 1891.

THE USE OF CADMIUM IN ASSAYING GOLD BULLION.

BY CABELL WHITEHEAD, Assayer to the Mint Bureau.

[*Presented at the stated meeting of the Chemical Section, held Sept. 15, 1891.*]

Cadmium, as a substitute for silver in assaying gold bullion, was first used by Balling.* He states that the gold is entirely parted from all metals, except the platinum group, when its alloy with cadmium is boiled with strong nitric acid for one hour, followed by a second boiling for ten minutes with fresh portion of same acid. For general assays of gold bullion I do not think that Balling's method with cadmium will bear comparison in point of accuracy with the old one of quartation with silver and cupellation. But, with certain modifications which will be suggested later, it will be found rapid and satisfactory for a preliminary assay.

It is, however, in the estimation of small quantities of silver in gold bullion containing considerable amounts of copper or platinum, that I have found cadmium to be a most efficient aid.

* *Crook's Select Methods of Chemical Analysis.*

The difficulty in determining silver in the presence of platinum by cupellation is well known to assayers. In such cases the following has been the method in the United States Mint at Philadelphia:

An approximate assay is made by cupellation, after which, and based on this approximation, enough pure silver is added to 500 mgs. of the bullion to make in all at least 1,004 mgs. of silver present in the assay. This weighed silver and bullion is wrapped in a sheet of lead weighing 2·5 gms., and the whole placed on a hot cupel in the muffle furnace.

As soon as the lead "clears" the cupel is withdrawn, when cold the button is flattened and put in a bottle such as is used in the humid assay of silver, dilute nitric acid is added and heat applied. When action ceases, the silver present in solution is determined volumetrically as usual. The silver found, less the amount added, gives the silver in 500 mgs. of bullion.

There are two objections to this method: (1) The insolubility of lead nitrate in nitric acid necessitates the use of dilute acid, which leaves much alloy with the gold; (2) the alloy to be removed is one-third silver. This is very important when small quantities of silver are to be determined, as in the case of gold coin, which rarely contains more than ·003. Cornets, after three boilings with acid (ten minutes each), retain from ·001 to ·002 of silver; so it will be seen at a glance that the amount retained after one boiling with dilute acid will be much greater and the gold residue will contain more silver than was present in the original bullion.

The presence of ten per cent. or more of copper in high grade gold bullion makes the accurate determination of silver by cupellation impossible. Not only is gold taken into the cupel in large quantities by the copper, but it is also left in specks over the entire surface covered by the assay, thus making a "proof" practically worthless.

The method which I am about to describe, was devised for the estimation of silver in gold coin, and has been in use in the laboratory of the Bureau of the Mint for the past

year, where it has given such satisfactory results that it is thought a brief description may prove of interest to others engaged in the same line of work.

Five hundred mgs. are weighed into a porcelain crucible and covered with ten gms. of potassium cyanide. The potassium cyanide is melted over a Bunsen burner or preferably a blast lamp. When the cyanide is in quiet fusion one gm. of cadmium is dropped into the crucible, where it quickly melts and forms a bright, homogeneous alloy with the gold. After gently shaking, so as to bring the cadmium in contact with every particle of bullion, the crucible is removed and the contents poured on a clean porcelain slab, where it soon solidifies. The alloy will be found in one piece and is easily detached from the potassium cyanide. It is now washed in warm water, dried and placed in a diamond mortar, when several sharp blows with a hammer quickly reduce it to powder.

This powder is carefully transferred to an assay bottle, 1004 mgs. of pure silver added and 10 cc. of nitric acid—32° Baumé—poured on. In from five to ten minutes (depending upon the heat used) the solution is complete and all action has ceased. The bottle is now cooled and 100 cc. of normal salt solution is charged and the bottle shaken. The precipitation is finished with the decinormal solution.

This assay is accompanied by another called a "proof," made of 1004 mgs. of pure silver dissolved in the same amount of acid. Now the excess of silver found in the assay over that shown in the "proof," is the amount contained in 500 mgs. of coin. This doubled gives parts of silver per thousand.

Example: An alloy composed of 499 mgs. pure gold, one mg. of silver and one gm. of cadmium, treated as above described, after being charged with 100 cc. normal salt solution, required five cc. decinormal solution for complete precipitation of the silver present. A proof assay, carried along as check, upon 1004 mgs. of pure silver, required in addition to 100 cc. of normal salt solution, four cc. of decinormal solution for complete precipitation = to 1004 cc.

decinormal solution. Hence, each cc. decinormal equals one mg. silver, and one cc. decinormal solution required by the bullion, in excess of that called for by the silver added, shows the bullion to contain one mg. silver in 500, or two parts per thousand.

It may be asked by those not familiar with mint appliances and usages, "Why not titrate directly the silver brought into solution with the cadmium instead of adding a known weight of pure silver and finding the desired result by difference?"

The reply is that the small amount of silver present in this class of bullion would, as chloride, not "clear" on shaking, and much time would be consumed in finding the end reaction. By the method described the usual apparatus and solutions may be availed of and results rapidly obtained.

When no such reasons exist the sulpho-cyanide method alluded to at the end of this article is recommended.

EXAMPLE IN GOLD BULLION.

An approximate assay gives by cupellation ·035 silver, hence, 500 mgs. will contain about 17·5 mgs. of that metal, and 986·5 mgs. must be added to bring the total silver up to 1004 mgs. If copper is not present, about 50 mgs. is added, it being found that the alloy of copper with cadmium is very brittle, and the resulting button is easily crushed to powder.

The sample having been fused with cadmium in presence of potassium cyanide is powdered and subjected to treatment with nitric acid as above described.

After charging with 100 cc. normal salt solution, and shaking, the assay required 4·5 cc. decinormal solution for end reaction. A "proof" consisting of 1004 mgs. pure silver in solution, treated in same manner, required but three cc. decinormal solution.

Hence the assay contained 4·5 — 3 = 1·5 mgs. more silver than the proof, or 1004 + 1·5 = 1005·5 mgs. in silver in all. This, less the 986·5 mgs. silver purposely added gives nineteen mgs. as the silver present in 500 mgs. of

bullion taken, or thirty-eight parts in each thousand instead of thirty-five parts found by cupellation.

In favor of the new method it may be said:

(1) That the ready solubility of cadmium in nitric acid of any strength, makes it possible to dilute (if the term may be used), the silver present in gold bullion, to any desired extent, while on the other hand the difficult solubility of lead necessarily limits the dilution possible by the time required for its even imperfect extraction.

The inevitable small portion of other metals retained by the gold after treatment with nitric acid may therefore, by the use of cadmium, be made to contain but an infinitesimal quantity of silver.

(2) The brittleness of the button obtained, permits its being crushed to a powder, in which condition the alloy rapidly yields its soluble portion to nitric acid, and the time required for an assay is materially shortened.

(3) The low temperature required enables the chemist to dispense with all special appliances. A Bunsen burner will well answer the requirements for heating purposes, and little more is needed beyond a standard salt solution. No muffle or rolls are wanted.

In a laboratory where few assays are made the following method might be followed and very satisfactory results obtained. After alloying and crushing, treat in a parting flask with fifteen cc. of nitric acid 32° Baumé for ten minutes, pour off this acid into a beaker, add fifteen cc. acid same strength and boil for ten minutes longer, pour off again in same beaker, wash with hot water and take out in an annealing cup, dry and heat over blast lamp, weigh and deduct ·25 mgs. for cadmium retained. Twice this weight gives the gold fineness.

The acid and washings are evaporated to drive off free nitric acid, and silver determined either as chloride, or volumetrically with sulpho-cyanide with ferric indicator. Cadmium nitrate does not interfere in the least with determination of silver, either as chloride or as sulpho-cyanide.

"PRESERVALINE," A NEW PRESERVATIVE FOR MEAT.

By Dr. Bruno Terne.

[*Read at the stated meeting of the Chemical Section, held May 19, 1891.*]

Some time ago, I was applied to for information as to how to pickle meat without the use of nitrate of potash or saltpetre. The objections to the use of saltpetre are said to be:

(1) The operation of curing takes too long a time.

(2) It renders the outside of the meat hard.

"There is a compound," my inquirer said, "that is used in large quantities in the West, and which avoids both these objections. What is it?"

I informed him that if he would procure me a sample of this material, or would, in lieu of this, furnish me either with a specimen of meat prepared with it, or with some of the pickle as prepared for use, I might be able to throw some light upon the subject.

Shortly after this, I came into possession of two samples both in pulverulent form, one red and the other white in color. I exhibit specimens of both of these preparations. From another source I learned that this product was placed on the market under the trade name of "Preservaline."

A qualitative test showed conclusively the absence of all nitrates and the presence of boracic acid in combination with a base, for the reason that the characteristic green coloration of the flame only appeared after the addition of a drop of sulphuric acid. It appeared further that both the red and white samples had the same composition, with the sole difference that to the colored sample there had evidently been added some rosanilin color.

I made up a sample with a little rosalic acid which exhibited nearly the same color as the original one but a little more pronounced.

The quantitative analysis of the white sample gave:

	Per Cent.
Biborate of sodium,	44·18
Chloride of sodium,	45·30
Moisture,	7·80
Impurities (undetermined),	2·82
	100·00

Practically then, we have here a mixture of equal parts of borax and common salt and the "Regular" preservaline, which imparts to the meat a cherry-red color, as per announcement of the manufacturers and vendors of this article, is simply the same product, with the addition of some coloring matter or dye.

I was aware that the use of coloring matters was largely employed in certain articles of food, especially in all candies and cakes, and the like, but it was somewhat of a surprise to learn that enterprise in this direction had progressed so far as to impose dyed meat upon us.

I investigated the red sample for traces of arsenic, which possibly might be contained in the color, but I am glad to report that I found none.

The solution of both samples was strongly alkaline. Without any doubt, this product, on account of the large quantity of borax in its composition, will act as a good preservative, but it is unquestionably a fraud upon the public, so far as the selling price is concerned, as the following statement will show:

	Cents.
One pound of borax is worth	9
" " " salt " "	1½
Two " " mixed salt is worth	10½
One " " " " " "	5¼

It is put upon the market for the prices indicated in the following tabulation, reproduced from the manufacturer's circular:

"REGULAR."

For Curing Pork and Beef.	*Per Pound. Cents.*
In barrels,	14
100 lb. kegs,	15
50 lb. drums,	16
25 lb. drums,	16
10 lb. box,	16

Use one pound for every 100 pounds of meat.

This preservaline gives the meat a cherry-red color.

"A."

For Pork and Liver Sausage.	*Per Pound. Cents.*
In barrels,	24
100 lb. kegs,	25
50 lb. drums,	26
25 lb. drums,	26
10 lb. box,	26

Sprinkle one-half pound over every 100 pounds of meat while being chopped or mixed.

"B."

For Bologna and Smoked Sausage.	*Per Pound. Cents.*
In barrels,	16
100 lb. kegs,	17
50 lb. drums,	18
25 lb. drums,	18
10 lb. box,	18

Use one pound for every 100 pounds of meat.

Preservaline prevents any kind of sausage from turning sour, even in the warmest weather, and retains the natural color of the sausage.

Looking over the literature of the subject, I found that a series of investigations of similar products had been made by Mr. G. Polenski, (*vide Reports of the Imperial German Health Office*, 1889, No. 5, p. 364).

I quote therefrom the following data, respecting the composition of a number of such materials.

(1) THE REAL AUSTRALIAN MEAT PRESERVER.

(A nearly colorless liquid, emitting a strong odor of sulphurous acid.) It contains in one litre:

	Grams.
Calcium oxide,	11·08
Sulphurous acid,	46·03
Ferric oxide (alumina),	·039
Silicic acid,	·052

(2) REAL AMERICAN MEAT PRESERVER.

(The same liquid, but a stronger solution.) Contains per litre:

	Grams.
Calcium oxide,	26·42
Sulphurous acid,	89·60
Ferric oxide (alumina),	1·80
Silicic acid, and alkalies,	1·20

(3) CONSERVATIVE FOR SAUSAGES.

(The same liquid, slightly opaque, but odorless.) Contains per litre:

	Grams.
Saltpetre,	33·40
Boracic acid,	27·50
Glycerine,	50·00

(4) PRESERVING SALT OF R. LEISENTHAL, COLOGNE.

(Does not redden the meat.)

Borax,	48·40
Water of crystallization,	39·00
Common salt,	3·44
Sodium bicarbonate,	9·10

(5) PRESERVING SALT OF THE SAME MANUFACTURER (TO MAKE THE MEAT RED).

	Per Cent.
Boracic acid,	28·34
Common salt,	9·58
Saltpetre,	57·35
Water,	4·50

(6) PRESERVING SALT OF GAASE BROS., BERLIN.

	Per Cent.
Boracic acid,	29·70
Saltpetre,	37·80
Common salt,	26·70
Water,	5·80

(7) AMERICAN HAM PRESERVER.

(An acid, yellowish liquid, having an empyreumatic odor.) Contains per litre:

	Grams.
Potash alum,	70·
Saltpetre,	21·04

(8) STUTTGART CONSERVING LIQUID FOR MEAT.

(An acid liquid, having a strong sulphurous acid odor and a yellowish color.) Contains per litre:

	Grams.
Arsenious acid (As_2O_3),	0·103
Common salt,	5·500
Phosphate of lime ($Ca_3(PO_4)_2$),	41·940
Sesquioxide of iron and alumina,	0·440
Sulphurous acid,	37·440
Free phosphoric acid (H_3PO_4),	6·050

9. SIMPLE CONSERVING SALT, OF CONSERVING SALT CO., HAGEN.

(A white salt, in solution, alkaline.) Contains:

	Per Cent.
Borax,	21·95
Water of crystallization,	13·30
Saltpetre,	33·10
Common salt,	32·04

10. TRIPLE CONSERVING SALT OF THE SAME MANUFACTURER.

	Per Cent.
Salt,	0·80
Boracic acid,	55·50
Borax,	29·00
Water of crystallization,	14·70

11. SAZOLITH.

	Per Cent.
Sulphate of soda,	37·3
Sulphurous acid,	39·7
Soda,	21·0
Water,	2·00

12. BERLINIT.

	Per Cent.
Common salt,	7·5
Boracic acid,	9·
Borax,	82·7

BERLINIT PICKLE (for reddening the meat).

	Per Cent.
Salt,	45·9
Saltpetre,	32·2
Boracic acid,	19·2
Water,	2·0

13. CHINA PRESERVING POWDER. (MINERVA.)

	Per Cent.
Common salt,	25·00
Boracic acid,	17·7
Sulphate of sodium,	38·8
Sulphite of sodium,	9·2
Water,	9·3

14. AUSTRALIAN SALT.

	Per Cent.
Common salt,	5·5
Borax,	94·00
Hydrocarbon (?),	0·5

15. DR. C. RUEGER'S BARMENIT.

Equal parts of borax and common salt.

This last brings us home again. American ingenuity, it will be perceived, is again in the lead. All the liquids and powders here referred to are free from coloring matter. They all use saltpetre to impart the red color to the meat, but the inventor of preservaline introduces the novelty of a dye to take its place.

The directions given by the manufacturer for the use of the red "regular" for curing pork and beef, prescribe one pound for every 100 pounds of meat. This is equal to one-half per cent. of borax.

The prescription for the white, for curing bologna and smoked sausages, indicates the same quantity.

We have no positive knowledge of the action of large quantities of borax upon the human organism, when taken internally, though there can hardly be any doubt that if taken even in small doses continuously for a considerable time its effect must be hurtful. This question, however, I leave to the decision of others better qualified for passing judgment upon it than myself. It was simply my intention to call to your notice the common use of borax as a preservative for meat, and especially the misuse of anilin red to replace in such mixtures the use of saltpetre.

The UTILIZATION of the BYE-PRODUCTS of the COKE INDUSTRY.

By Dr. Bruno Terne.

[*Read at the stated meeting of the Chemical Section, held Oct. 20, 1891.*]

About a year ago I had the honor to speak in the lecture course of the Franklin Institute on ammonia, its sources and technical uses.

I dwelt for reasons which I thought of sufficient importance, especially on the production of ammonia as a bye-product of the coke industry.

We have now entered upon the beneficial workings of the new policy of furthering industrial developments in new branches in a period which requires the technical men in all branches, and especially in the chemical industries, to call the attention of the capitalist to the points in which we are behind the times in our developments, to the points where the resources of our own land are neglected, and we are far behind the more progressive European manufacturers.

I thought it of sufficient importance to ventilate the same question before the Chemical Section of the Institute in order to create an interest in the circle of the members of the Institute, who are the best judges of such questions, in order to provoke criticism of my views.

I have revised the part of my lecture referring to the development of the ammonia industry for this purpose, not in the expectations of claiming new and original ideas, but to secure your attention to a point which I consider of great importance for the development of an important branch of the chemical industries.

We are surrounded by an immeasurable quantity of nitrogen gas in the atmospheric air.

The weight of the atmosphere surrounding our earth is calculated to be ten trillions of pounds, of which 7·77 trillions pounds are nitrogen; but in spite of this inexhaustible source of nitrogen, we are not able in a direct way to use a single pound for the production of ammonia.

It has long been the endeavor of the technical chemist to convert the nitrogen of the air into ammonia, but up to this hour none have succeeded in doing it with practical results. We are still compelled to use as sources for the production of ammonia, the products of plant or animal life.

The nitrogen of the air must pass through the channels of plant life to reach in the products of the animal body their highest degree of concentration.

Hoofs and horns with fifteen to sixteen per cent. dried blood, with nineteen per cent. hair and wool waste, with ten per cent. bones, with five per cent. of ammonia, are the richest sources.

But the products of animal life, however, even if they were not too valuable otherwise, are by no means sufficient to satisfy the wants of the present day for the products of ammonia. But Nature has provided an inexhaustible source for hundreds of years to come, in the residuum of plant life of former periods. In the bituminous coal fields and in the deposits of brown coal are lying stored up, billions of pounds of nitrogen waiting to be converted into ammonia.

The process of gaining this ammonia is incidental to the production of illuminating gas, to the production of coke, and to the production of animal charcoal.

In distilling the bituminous coal we obtain of the weight of coal used:

4–6 per cent. of tar and 6–10 per cent. of ammoniacal water of 1°·8 B.

As Prof. Lunge has shown, the nitrogen contained in the coal does not yield the amount of ammonia which we might expect :

Name of Coal.	*Yield of Nitrogen. Per Cent.*	*Possible Yield of Ammonia. Per Cent.*	*Possible Yield Ammonia Water. 1·020 spec grav. Per Ton of Coal. Gallons.*
Wales, ...	0·71	1·10	142
Lancashire, ...	1·25	1·52	196
Newcastle, ...	1·32	1·60	206
Scotland, ...	1·44	1·75	226

But instead of these figures, the practical yield per ton of coal at the best is only forty-five gallons of gas water of 1·020 sp. gr., generally only twenty-five gallons, and in some instances, as low as thirteen gallons.

The ammoniacal liquors from distillation of animal refuse are much richer, but the small quantity produced allows us to ignore the same as a very insignificant factor in the production of ammonia salts.

The consumption of ammonia in its various forms has grown enormously in the last twenty years, and the manufacture of illuminating gas is no longer sufficient to supply the increasing demand for ammoniacal liquors. On the other hand the inroad which electrical plants for illumination have been making yearly on the production of illuminating gas, has already been felt, and will be more so from year to year. The production of water gas and oil gas are other factors which are cutting down the amount of ammoniacal waters produced.

But there is another source for tar and ammonia, which, so far as my knowledge goes, has, with a single exception, not been worked in our country.

Rich as are our resources, we are not rich enough to waste continually.

It seems strange, and nevertheless it is a fact, with all the ingenuity of the American people in the advancement of the purely mechanical part of the technical industries, we have been and are yet slow in the development of the chemical industries.

The acid manufacturer of Europe, especially of England

and Germany, had commenced in the beginning of this century to make himself independent of the sulphur mines of Sicily by using the sulphurous ores of his immediate neighborhood, and to utilize the pyrites for making his sulphuric acid. It has been only within the last twenty years that our people commenced to use the ores which had been lying under their feet, and to-day even, the United States consumes more sulphur for the manufacture of sulphuric acid than any other nation.

It is the same with productions of tar and ammonia as a bye-product of the manufactures of coke.

If you will visit our coal region to-day, you will find the nightly sky illumined from the fires of the coke ovens, and every one of the brilliant fires bears testimony that we are wasting the richness of our land in order to pay the wiser European coke manufacturer, who saves his ammonia an sends it to us in the form of sulphate of ammonia; and who also saves his tar, which, after passing through the complex processes of modern organic chemistry, reaches our shores in the form of aniline dyes, saccharin, nitrobenzol, etc.

As far back as 1768 tar had been produced as a bye-product of the coke industry by a chemical process at Fishbach, in the coal district of Soarbrücken on the Rhineland.

The general opinion of the consumer there was then, and most likely will be here at the present time, that the coke produced will be of inferior quality. Against this opinion of the practical coke men, it has always been held by technical chemists, that the process can be so conducted as to yield all the bye-product and still make a first-class coke.

Since about 1850, the producers of coke in France, Belgium, England and Germany commenced simultaneously the saving of the bye-products.

At St. Etienne, in France, a system of furnaces was at work in 1862 for which great success was claimed at that time. The gas and other volatile products of the coke oven were conducted to an air condenser, in which the tar and ammonia were condensed; the non-condensable gases were returned to the furnace as fuel.

Scrubbers and condensers have been improved to insure complete condensation.

The following average results have been claimed:

	Per Cent.
Coarse coke,	70
Small coke,	1½
Waste coke,	2½
Graphite,	½
Tars,	4
Ammonia water,	9
Gas,	10·58
Loss,	1·92

The net gain after deducting all expenses and without reckoning in the coke was, per oven, in Bessèges which has eighty-five ovens in operation, 111,446 francs. For eighty-five ovens this saving amounts to 94,690 francs or about $18,938.

I give you in the accompanying table, the results reported from two establishments in France.

I will not endeavor to cover the development of the coke industries of Europe for the whole period since 1850. I have had occasion to familiarize myself with all the conditions of this industry, and am in possession of figures and plans of Dr. Otto's successful ovens, a view of which I show you. (See accompanying plate.)

In 1883, a system of twenty ovens were built at the coke works of Gottesberg, Silesia, the results from which were so encouraging, that in the following year 120 ovens were built.

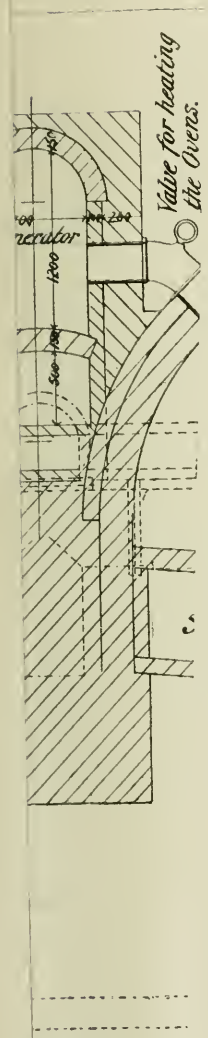
I will give you a report from a manufacturer, who, two summers ago, visited the Dahlhausen works of Dr. Otto, at the mines of Millensiven near Dortmund. Here, there are two sets of thirty ovens each, which are charged alternately every other day. The gases are conducted by large iron pipes to a large basin, where a part of the tar will be condensed. From there it is led to the coolers, where the remaining tar and ammoniacal products are absorbed, and the gas purified is returned to a gas holder, and from there is redistributed to the coke ovens, to the boiler fires and utilized as illuminating gas throughout the works. The gas returning to the coke ovens is mixed with hot air, and enters the flues

of the bottom and sides. The coke produced is an excellent product, and finds a ready market everywhere. It has not

Name of Works.	Number of Ovens.	Tons of Coal Consumed.	Yield of Coke.			Tar.			Ammonia Water.		Sulphate of Ammonia.		
			Total Tons.	Prac. Per Cent.	Per Oven.	Total Tons.	Per Cent.	Per Oven.	Hectolitres.	Per cent.	Per Hectolitre. Kilograms.	Per Oven. Tons.	Per Ton of Coal Kilo-grams.
1879. Bessèges, ...	85	46,902	33,092	70·55	389·3	1,096	2·23	12·89	44,932	9·6	6·5	3·435	6·22
Terrenoire, April 1 to December 31, 1879, . .	100	38,427	26,293	68·42	—	966	2·50	—	36,205	9·72	7·6	—	—
Per annum calculated, .	—	—	—	—	350·57	1,288	—	12·88	—	—	—	3·374	6·54

the silver gray or steel color of our Connellsville coke, but it is quite as good in quality as ours.

The person who pronounces this verdict was then, and



Furnace.

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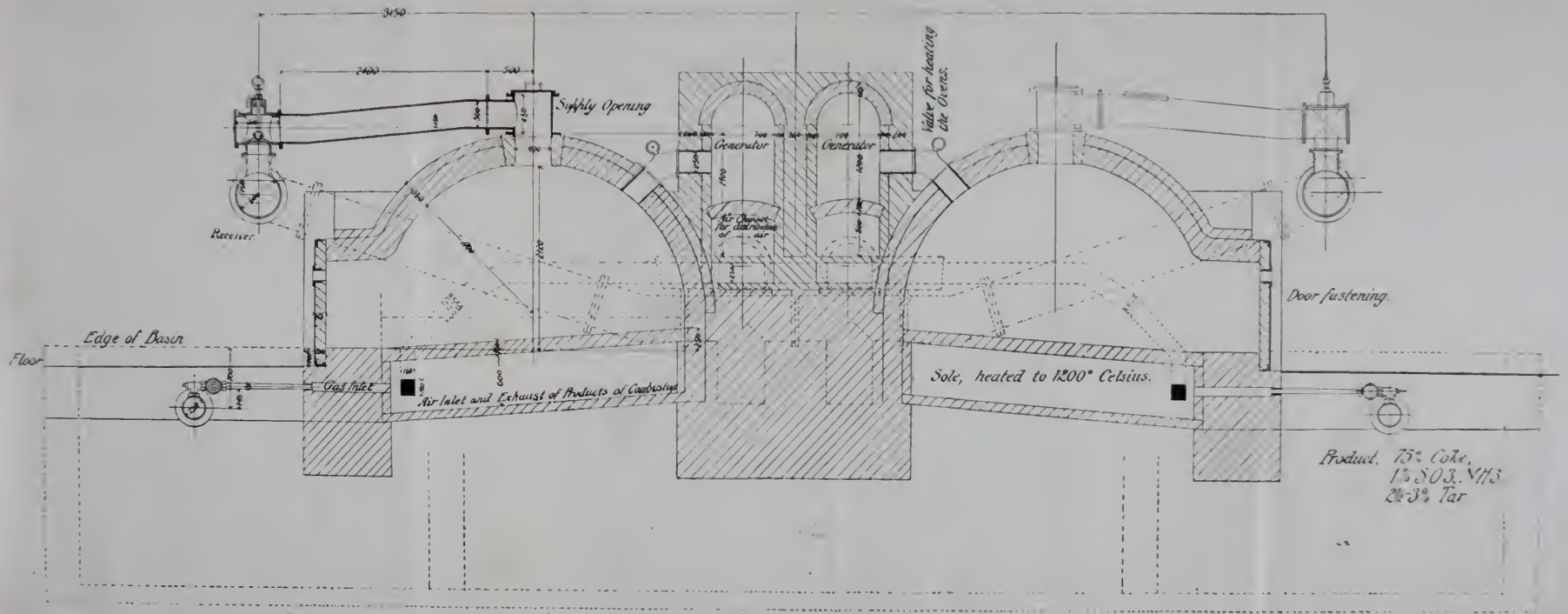

Dr. Otto's Improved Coke Furnace.

is now, connected with one of the largest iron works of our state, and thoroughly well informed upon every point of blast furnace produce, and familiar with the qualities of coke produced and used in the Connellsville region.

He repeated, after having explained to me how even the same color could be made, that the quality of this coke is in every respect equal to that of Connellsville. "But," he added, "I desire to call your special attention to the statement, 'The oven of Dr. Otto yields seventy to eighty per cent. of coke, while our Connellsville 'Beehive' oven will only yield fifty-five to sixty per cent.'"

Dr. Otto builds these ovens at his own expense, runs them for twelve years, taking the coal from the mines and delivering the coke to the mine company, for the yield of tar and ammonia, and at the end of the term surrenders the whole plant to the mine owners. He must make in this time from the value of the bye-products alone, the cost of the ovens, the interest of the capital invested and the legitimate profit of a manufacturer, and he is successful in doing it. Don't you think that we can achieve the same results here?

In the year 1887, there were in operation in 279 establishments in the United States, 26,001 ovens, and 3,594 ovens in course of erection.

These ovens consumed 11,859,753 tons of coal, producing 7,611,705 tons of coke, a percentage of 64·2. Calculated on the basis given in the table before you, the possible yield of sulphate of ammonia from this quantity of coal, *i. e.*, 12·8 pounds per ton, will give us the enormous figures of 151,-804,838 pounds of sulphate of ammonia, which at three cents per pound only is equal to $4,554,746.

Pennsylvania is the principal coke-producing State in the Union.

Seventy-six and six-tenths of the coke used in the United States is made within her borders.

The number of establishments were, in 1887, 151, with 18,294 ovens, which produced 5,872,847 tons of coke, a yield of sixty-five per cent. The Connellsville district, of Pennsylvania, is one of the most important of the world. The Connellsville basin is in the southwestern part of the State,

some fifty or sixty miles from Pittsburgh. In this district were made 4,146,989 tons of coke, or 57·4 per cent. of all the coke made in the States.

At three works, during the year 1886, careful weighings were carried on, with the following results:

	Coal Charged.	*Coke Produced.*	*Per Cent. Yield.*
No. 1,	230,585	157,070,40	68,118
" 2,	60,934	40,947,09	67,188
" 3,	63,893·2	42,927,24	67·2
Total,	355,421·2	240,944,64	67·8

The coal used in Pennsylvania in 1887, for making coke, was 8,938,849 short tons.

If this had been done, with saving of the bye-products, 178,776 tons of tar and 114,417,267 pounds of sulphate of ammonia, or 7,208 $\frac{1267}{2000}$ tons of sulphate of ammonia could have been produced, which represents in ammonia salt alone a value of $3,432,480; or, to illustrate in another way, 28,604,316 pounds of ammonia, which has an agricultural valuation of eighteeen cents per pound, have been lost to the industrial and agricultural interests; or, at the valuation of the agricultural experimental stations, the loss of a single year was $5,128,776 $\frac{88}{100}$.

I am very well aware that these figures are imaginary, as under the best possible circumstances not all the coke ovens could readily be arranged for the saving of bye-products but if one-eighth or one-half of the total production were united with saving of the bye-products, from one to two millions a year on ammonia only could be produced in this State alone.

You will ask, Will the Connellsville coal give the same result as the German coal? Without hesitation, I answer, it will.

There are here five samples of coal from the Connellsville district, which have been analyzed in my laboratory, with the results given below:

	Per Cent.	
No. 1,	1·76	ammonia
" 2,	1·26	"
" 3,	1·90	"
" 4,	1·80	"
" 5,	1·80	"

These analytical results place the coal of the Connellsville region on an even footing with the bituminous coal of the district, where the bye-products of coal are gained in making coke.

There are numerous systems of coke ovens in Europe, but none has been more successful than the ovens mentioned above. Whatever the system may be, the products of condensation must be separated; the tar from the ammoniacal waters, and each worked according to its specific requirements. In England, the escaping gases of blast furnaces have in two instances been worked for ammonia. I am unable, however, to say anything about results.

The interest of the manufacture of ammonia requires that the liquors should be as concentrated as possible, and still leaving the gases escape as free as possible from ammonia. To accomplish this, certain improvements in apparatus have come into use. The older construction of scrubbers, or apparatus for washing the gases, has been superseded by mechanical scrubbers. One of the latest constructions of such a scrubber is the one represented in the accompanying illustration. It is the form constructed by the Director of the City Gas Works, in Chemnitz, Saxony, and adopted by the best authorities of Germany as one of the most economical working forms of the apparatus.

The mechanical scrubber of E. Ledig* is based on the principle of the rapid absorption of ammonia by water distributed over a large surface, which is heated by a system of plates alternately dipping in water and raised out again, thus offering the gas the large surface of the combined plates. This up and down movement creates new surfaces for absorption with each motion, and secures a complete washing of the gas. The ammoniacal liquor so gained has now to be worked so as to gain the ammonia from it in order to prepare the different ammonia compounds.

The ammoniacal liquors contain free ammonia, carbonate of ammonia, sulphide of ammonium, sulphocyanide of ammonium, tartrate of ammonia, sulphite of ammonia, chlor-

* U. S. Patent, No. 407,937, July 30, 1889.

ide of ammonium, sulphate of ammonia, organic ammonia compounds, such as amin, pyridin, etc.

The ammonia waters contain in one litre, from coals of the

		Grammes.	
District	Zwickau (Saxony), ...	37,943	ammonium salts.
"	Ruhr (Rheinland), ...	29,402	
"	Saar "	43,225	
"	" "	9,506	

You will notice that the differences in yield are very wide, but nevertheless the smallest amount named is sufficient to make the gain, the bye-products, in the commercial scale, a profitable operation.

The oldest methods of gaining the ammonia were to saturate the liquors directly with sulphuric acid in large tanks. The cost of evaporating such enormous quantities of water and the impure condition of the product soon led to the invention of improved methods.

Tanks, or a system of tanks, were heated directly by fire or steam, and the volatile ammonia driven out to be absorbed by the acids in the receivers.

The newest improved forms of apparatus are those constructed by the well-known manufacturer of chemical products, Dr. Grüneberg, of Cologne, and by Dr. Feldmann, of Bremen. Both of these are constructed on the same principle, viz: a current of steam moves in opposition to the movement of the liquor. The richest liquor comes in contact with the nearly saturated vapors and the weakest liquor with the fresh steam.

These forms of apparatus have superseded in Europe, especially in England and Germany, the older devices.

The accompanying engraving (*Fig. 1*) shows the construction of the Grüneberg apparatus.

The apparatus of Dr. Feldmann is still simpler and is, therefore, preferred by a great many manufacturers of ammonia salts. (*Fig. 2.*) Both of these devices are patented in the United States.

The Feldmann apparatus cannot be excelled for economy of steam and reliability in service; its capacity for working five to twenty-five tons of liquor daily makes it likewise

desirable for a rural gas works as well as large establishments.

The question Will it pay to gain the bye-products of the manufacture of coke? has been practically solved in the affirmative. The numerous objections have, step by step, been overcome. The industry of the coke production com-

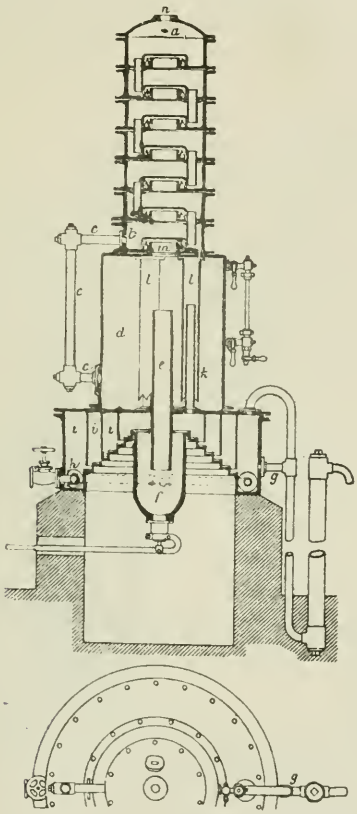

FIG. 1.—The Grüneberg Ammonia Still.

bined with the saving of the bye-products is an established fact in Europe, and will be here also in the near future. What system of ovens will be found best adapted to our wants, may be an open question to decide, which rightly will require the consideration of a great many points of local importance.

The system which I have described is one of the most successful of those used in Germany to-day.*

I advocate the Otto system because I know of its merits and advantages from a careful study of it, and lengthy correspondence with the inventor.

The results obtained by Dr. Otto, Copper and others, exhibit such decided progress over the past, that it is only

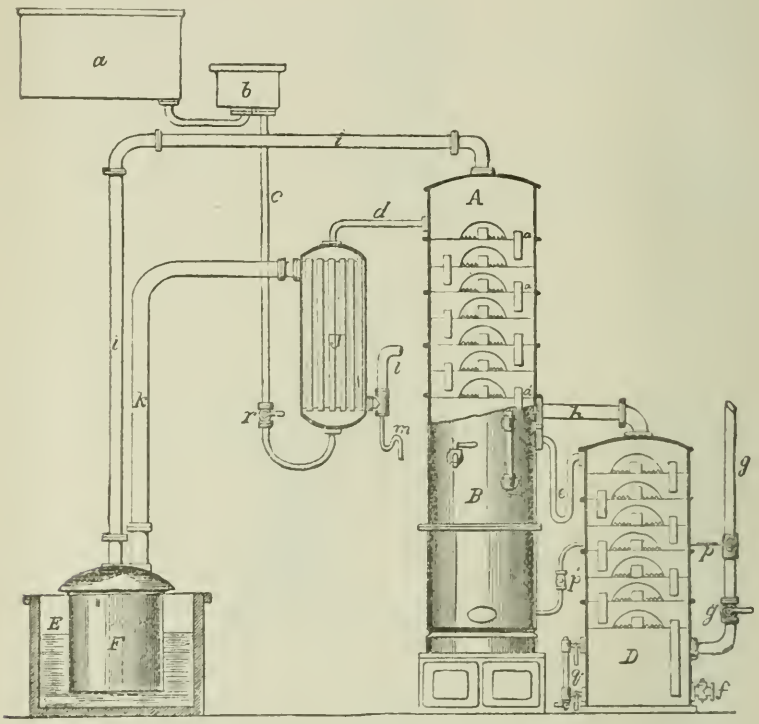

FIG. 2.—The Feldmann Ammonia Still.

a question of time when the coke producers of the United States must fall in line.

The advance in the coke industry will cause an advance in the tar color industry, and will further the growth of the soda industry based on the ammonia process.

* The latest improvements are covered by D. R. P. 52,206, Universal coke-oven, C. Otto and F. W. Larmann.

If I have succeeded in adequately exhibiting the importance of saving the valuable products at present wasted in our coke industries, I shall have accomplished my purpose.

Until every pound of ammonia used in our land is produced in our land, until every pound of soda is made from our own salt wells by the ammonia process, we will continue to be dependent upon the chemical markets of Liverpool and London.

DISCUSSION.

Dr. H. W. JAYNE: No one will deny the importance of the subject presented to us this evening by Dr. Terne, and I am aware that it has been carefully investigated by a number of large firms in the country, but as yet nothing has been done.

Coke operators fear that it would be difficult to overcome the prejudice against the coke as it has not the silvery appearance of the Connellsville article.

The great first cost of the plant is another serious obstacle. An ordinary beehive oven to work about 480 tons per year costs about $280, while a Carves oven of the same capacity costs complete with the coolers and all appliances $845 each, and Otto ovens of 1,000 tons capacity would cost $750 for ovens, and $1,450 for coolers and all other machinery and buildings. The above figures were furnished by the respective inventors.

In addition, the present beehive oven is of extremely simple construction, and can be run by the most unskilled labor, while the improved ovens are complicated and require nice working and constant repairs to prevent loss of gas, and consequent loss of the bye-products.

There can be no doubt that eventually such ovens will be introduced, and when in successful operation, other coke producers will be compelled to erect them, as they could not possibly stand the competition caused by ovens producing not only such valuable bye-products, but also such a greatly increased yield of coke.

Dr. TERNE said: I would like to state, that according to Dr. Otto's figures in my hand, the cost per oven, without condensation apparatus, is 1,508 marks ($377.) Or, for a battery of thirty-eight ovens, with complete condensation apparatus:

(I) 38 ovens,	57,304	marks.
Condensation apparatus,	117,683	"
	174,987	"
Equal to,	$43,746	75
Or, per oven,	1,151	20

It is well to state here that the apparatus of condensation for the winning of the bye-products will outlast the life of the ovens many times; the first cost will, therefore, be limited to the first system erected.

Mr. HENRY BOWER referred to a short article which he had recently seen in the *Chemical Trades Journal* of Manchester, England, in which it was stated that it was not certain whether certain firms of speculators were not contributing to the depression in the prices of anthracene and benzole in the hope of frightening investors from opening additional carbonizing works. Mr. Bower also referred to the depression existing in the prices of sulphate of ammonia, and the influence of tar-producing concerns in Philadelphia against the carbonizing process.

Dr. JAYNE: The statement, referred to by Mr. Bower, which appeared in the *Chemical Trades Journal*, of Manchester, referred to the fact that the large production of benzole by the coke carbonizers prevented the extreme prices which would otherwise prevail owing to the great consumption of this article at present, especially in the preparation of medicinal articles.

Before the carbonizing plants were in operation benzole fluctuated very violently, ranging from thirty cents to $1.25 per gallon in one year.

The large amount of benzole produced by the coke plants is not obtained from the tar, which contains only a small quantity, but from the gases, which contain about twenty-five times as much as the tar.

In our cities it is impossible to remove this benzole from the gas, as it would at the same time remove most of the illuminating properties, but the coke gases can be cooled and washed with oils removing most of the benzole.

The inventors of the Simon-Carves oven claim that they can thus obtain three-fourths of a gallon of a high grade benzole from one ton of coal. It may be interesting to note in this connection that there are, or were, several plants running in England carbonizing coal in gas retorts entirely for the bye-products, as such coke is of little value. One of these works at the "Talk of the Hill" Collieries had 300 retorts in use producing 12,000 gallons of benzole per month.

Dr. TERNE: In reply to the remarks of Mr. H. Bower, I beg to say that the influence of the tar-producing companies of Philadelphia will not be dominant enough to prevent the development of this branch of chemical industries.

The combined interest of the larger producers and consumers of tar and ammonia will finally regulate the development of this industry.

To the further remarks of Mr. H. Bower, I should answer that I desire it distinctly to be understood that I do not advocate the producing of coke only for the gain of ammonia.

The higher yield of coke, the gain of the tar, with the daily increasing demand for same, and the gain of the ammoniacal water are the inducements which are given by the new methods.

The temporary depression in the price of sulphate of ammonia will not last, and even yet at ruling low prices we have not reached two and one-half cents per pound as on the other side.

We do not need to be frightened by wages; it will cost very little more to make coke and gain the bye-products than it now costs, and the slight additional cost will be amply repaid by the tar and ammoniacal water.

The cost of sulphuric acid does hardly come in play, first because we get a higher price for sulphate of ammonia produced, and second, we do not need to turn the ammonia in sulphate.

The ammonia soda industry of this country is in its infancy, and the demand of concentrated ammoniacal waters for the same will be steadily increasing.

The development of these industries is bound to come in spite of all objections, and it will be not so far off either. The right start is the most difficult point.

PROCEEDINGS

OF THE

ELECTRICAL SECTION

OF THE

FRANKLIN INSTITUTE.

[*Proceedings of the stated meeting, held Tuesday, October 6, 1891.*]

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, October 6, 1891.

Prof. EDWIN J. HOUSTON, President, in the chair.

Present, twenty-one members and visitors.

The minutes of the previous meeting were read and approved.

One nomination to membership was referred to the Committee on Admissions. The committee reported six elections since last meeting.

It was moved and carried that the President appoint a committee of three members to secure papers for the meetings.

Mr. H. W. Bartol was unable to present his paper on "The Electric Railway of Buda-Pesth," not having received the expected data with regard to it.

Prof. Edwin J. Houston described the probable production of electricity from light in the leaves of plants, and promised a more formal presentation of the subject later. In the discussion that followed, the analogous action in the selenium cell and applications of it were described.

The Question-box contained queries on the advantages and disadvantages of slow speed in motors, the practical working of the Evans frictional method of driving, the latest theory with regard to the earth's magnetism, and the practicability of dispensing with earth connection for lightning rods—all of which were discussed at some length.

The Chair appointed on the Committee to secure Papers, Dr. Wahl (Chairman), Messrs. Carl Hering and Pike.

The meeting then adjourned.

L. F. RONDINELLA, *Secretary.*

CORRESPONDENCE.

THE PATH OF A PROJECTILE.

To the Committee on Publications.

GENTLEMEN:—The formulæ deduced by Mr. Gilman, in the *Journal* for October, relative to the path of a projectile on the hypothesis of a resistance varying directly as the velocity, may also be found (or their equivalents) in Captain Ingalls' *Exterior Ballistics in the Plane of Fire*, a text-book used at the artillery school, Fort Monroe, and published by Van Nostrand, in 1866. It is believed that the applications of these simple and analytically exact formulæ to modern gunnery are there given for the first time. The author of this text-book gives a table of the values of Mr. Gilman's "c" (or rather

$$\frac{d^2}{cw}$$

d being the diameter, and w the weight of the projectile) for the muzzle velocities commonly employed in mortar practice, deduced in a novel manner from Bashforth's experiments, at Shoeburyness, England. He applies these formulæ, in connection with the table, to the computation of the ranges and times of flight of mortar shells fired with angles of projection varying from 30° to 60°, and compares the computed ranges with those observed at the Krupp proving ground, Meppen, and finds an average discrepancy between computation and experiment, of considerably less than one per cent.

Captain Ingalls' formulæ (which are equivalent to those deduced by Mr. Gilman) give the time of flight and horizontal range between two given points, as functions of the horizontal velocities at those points.

If one of the points is the "point of projection," and if we write

$$U = V \cos \alpha$$

$$u = v \cos \theta$$

we have for the time of flight and horizontal projection of the trajectory, the simple equations

$$t = \frac{1}{c} \log \left(\frac{U}{u} \right)$$

$$x = \frac{1}{c} (U - u)$$

Eliminating u from these equations gives Mr. Gilman's equation (5). For the equation to the trajectory we have

$$y = \left(\frac{g}{c\,U} + \tan \alpha \right) x - \frac{g\,t}{c}$$

or, substituting for t its value in terms of x, gives Mr. Gilman's equation (7).

For the relation between the horizontal velocities and the inclinations of the tangents at two points of the trajectory we have

$$\tan \alpha - \tan \theta = \frac{g}{c}\left(\frac{1}{u} - \frac{1}{U}\right)$$

Combining this with the expression for x gives

$$x = \frac{U u}{g}(\tan \alpha - \tan \theta),$$

while the corresponding expression for x *in vacuo* is

$$x = \frac{U^2}{g}(\tan \alpha - \tan \theta).$$

It follows from these last two equations that if U, α and θ are the same in both trajectories, their horizontal projections between the two given points, or points of equal inclination, are proportional to the horizontal velocities at those points.

JAS. M. INGALLS,
Capt. 1st Art'y.

Fortress Monroe, October 13, 1891.

THE STEAMLOOP.

To the Committee on Publications.

GENTLEMEN:—I was pleased to note, in the October *Journal*, a very able article by Mr. Walter C. Kerr, on the "Steamloop." While the literature on this minor subject is perhaps not as full as might be expected, still the subject itself has been quite thoroughly exploited in a practical manner many years ago. The first time this subject was called to my attention was, I think, in 1873, by a salesman, who was selling a so-called "steam trap," the manufactory thereof being located somewhere in central New York; the exact location I do not now recall, nor the name of the concern. However, the firm in whose employ I then was purchased three of these traps. The trap consisted of a ribbed globe about ten or twelve inches in diameter, which acted as a condenser. On top of this globe was an air valve and also a branch pipe, leading to a vessel corresponding to the device now called a "separator." The globe was elevated about ten to fifteen feet above the boiler, and the bottom of the same connected with the boiler below the water line with a check-valve, etc. There was also a check-valve near the condenser globe in the pipe leading from the separator. The first of these three devices was set up and put into operation by me in Hudson, Wis., for the West Wisconsin Railroad, either in 1873 or 1874, and worked very perfectly and completely through about 350 feet of line, the separator being perhaps eight to twelve feet below the water-line of the boiler. Its initial operation was so satisfactory that two more were ordered, one for the State's Prison in Stillwater, and one for the State House in St. Paul. However, a more extended use of the first appliance in connection with a heating apparatus of considerable magnitude, developed the facts Mr. Kerr refers to; that is, the liability of "flooding" to such an extent that all three of the devices were

subsequently abandoned, and other devices substituted therefor. At various times during the past sixteen years, I have used this device for a single radiator or single heating device, with very satisfactory results. In 1875, I put the device on a brewer's kettle, in St. Paul, but its operation was not very satisfactory, and more so, perhaps, through the prejudice of the brewer than for any inherent defects in the device itself. I do not know who the original discoverer of the device was, but I believe it to have been Mr. James H. Blessing, of Albany, N. Y. However, my experience with its use has been that it was more satisfactory on the steam pipe leading to an automatic engine than in any other place, owing to the effect produced by the momentum of the current of steam in the pipe, when the induction valves of the engine closed.

As a matter of curiosity, if any one knows, I would like to know who was the original discoverer of this method of handling the water of condensation, primage and entrainment, and where it was first used.

Respectfully yours,

E. F. OSBORNE.

Chicago, October 5, 1891.

BOOKS RECEIVED.

[In sending books for notice in the *Journal*, publishers are requested, for the information of the reader, as well as for their own advantage, to give the price. This announcement by title will be followed, in most cases, by a review, which will appear at the earliest opportunity.]

Manual of the Steam Engine for Engineers and Technical Schools. Part 1. Structure and Theory by Rob't H. Thurston. New York: John Wiley & Sons. 1891. 8vo, pp. 871., Price, $7.50.

Guides for Science Teaching. No. 8. Insecta. By Alpheus Hyatt and J. M. Arms. Boston: D. C. Heath & Co. 1890. 12mo, pp. 300. Price, $1.

WOODBRIDGE SCHOOL ESSAYS. No. 1. *Theoretical Astronomy. Dynamics of the Sun.* By J. Woodbridge Davis. New York: Woodbridge School. 1891. 4to, p . 97.

Zodiacal Light. By M. A. Veeder. Rochester: Academy of Science. 1891. 8vo, pp. 10.

Elektrotechnische Bibliothek. Band 43. Die Elektrischen Verbrauchsmesser. Von Etienne de Fodor. Wien: A. Hartleben. 1891. 12mo, pp. 219. Price, 75 cents.

Plane and Solid Geometry. By Seth T. Stewart. New York: American Book Company. 1891. 12mo, pp. 406. Price, $1.12.

Théories Modernes de l'Électricité. Essai d'une théorie nouvelle by O. Lodge. Traduit de l'Anglais et annoté. Par E. Meylan. Paris: Gauthier-Villars. 1891. 8vo, pp. 216. Price, $1.25.

Transition—Curve Field-Book. By Conway R. Howard. New York: John Wiley & Sons. 1891. 12mo, pp. 109. Price, $1.50.

Maximum Stresses under Concentrated Loads treated Graphically. By Henry T. Eddy. New York: D. Van Nostrand Company. 1890. 8vo, pp. 100.

Traité d'Électricité et de Magnetisme. Par A. Vaschy. Paris: Baudry et Cie. 1890. 2 vols. 8vo. Price, $5.

Appleton's School Physics. By John D. Quackenbos, Alfred M. Mayer, Francis E. Nipher, Silas W. Holman, Francis B. Crocker. New York: American Book Company. 1891. 12mo, pp. 544. Price, $1.20.

Theory of the Continuous Girder. By Malverd A. Howe. New York: Engineering News Publishing Company. 1889. 8vo, pp. 119.

Principles of Agriculture for Common Schools. By I. O. Winslow. New York: American Book Company. 1891. 12mo, pp. 152. Price, 60 cents.

Patent Franchise of the United States. By G. H. Knight. New York: 1891. 8vo, pp. 24.

Short Manual of Analytical Chemistry. Qualitative and quantitative—inorganic and organic. By John Muter. First American from the fourth English edition. Edited by Claude C. Hamilton. Philadelphia: P. Blakiston, Son & Co. 1891. 8vo, pp. 206. Price, $2.

Irrigation Statistics of the Territory of Utah. Compiled and prepared for the Irrigation Congress. By Chas. L. Stevenson. Salt Lake City. 1891. 8vo, pp. 36.

Nu English. A proposed simplified language for home use and for International commerce and travel. By Elias Malee. Minneapolis: Author. 1890. Pp. 32. Price, 25 cents.

John Wiley & Sons announce, as in preparation, *A Manual of Mining.* By Prof. M. C. Thesing, Golden, Col.

BOOK NOTICES.

A Hand-Book of Industrial Organic Chemistry. Adapted for the Use of Manufacturers, Chemists, and all Interested in the Utilization of Organic Materials in the Industrial Arts. By Samuel P. Sadtler, Ph.D. Philadelphia: J. B. Lippincott Company. 1890.

This large octavo, of 519 pages, is the first of its kind to appear in America, and if we except one or two antiquated translations, it is the only single volume on applied chemistry in the English language. The whole is divided into fourteen chapters as follows:

I. Petroleum and Mineral Oil Industry.
II. Industry of the Fats and Fatty Oils.
III. Industry of the Essential Oils and Resins.
IV. The Cane Sugar Industry.
V. The Industries of Starch and its Alteration Products.
VI. Fermentation Industries.
VII. Milk Industries.

VIII. Vegetable Textile Fibres.
XI. Textile Fibres of Animal Origin.
X. Animal Tissues and their Products.
XI. Industries Based upon Destructive Distillation.
XII. The Artificial Coloring Matters.
XIII. Natural Dye Colors.
XIV. Bleaching, Dyeing and Textile Printing.

Some of these include more than would at first appear, for instance, Chapter X treats of the leather industry as well as those of gelatin and glue, and Chapter VI of wine-making, the manufacture of distilled liquors, bread-making and the manufacture of vinegar.

Each chapter or subdivision is systematically arranged into:

(1) Raw Materials.
(2) Process of Treatment.
(3) Products.
(4) Analytical Tests and Methods.
(5) Bibliography and Statistics.

This plan of treatment has enabled the author to present the subject compactly, and it also admits of being readily grasped by the reader.

The bibliography forms an important part of each subject as it should in all works of this character. The same might be said of the statistics; and both when brought closely up to date, as in the present work, are of the greatest value to the manufacturer.

There are 127 illustrations and fourteen diagrams distributed through the volume, which assist the descriptions and add to the value of the work. An Appendix of over twenty pages embraces the metric system, tables for the determination of temperatures, specific gravity tables and alcohol tables.

It is evident the author has not made a mere compilation, but that he has drawn largely from his own experience as teacher and expert, the latter capacity having given him opportunities to study many processes where they are conducted on a commercial scale. Where he has not had all the desired experience in certain technical work he has availed himself of the assistance of others in these special subjects; this is particularly the case in Chapter XIV.

That the French and Germans are so well supplied with such books, while we hitnerto have had none is remarkable and difficult to explain, unless we attribute it to the disposition of the American manufacturer to invent and keep secret his own processes.

The author, no doubt, felt the need of a work both in his teaching and practice, that would not only describe the various organic technical processes, but also bear more directly on those chemical industries which are peculiar to this country, descriptions of which are, therefore, not to be found in foreign books. In supplying this demand he has prepared a volume that will be appreciated by other chemists, as well as by those who wish quickly to gain a knowledge of special processes, as is frequently the case with attorneys and others interested in patent suits.

The book is written in a clear, interesting style that will make it attractive to the general scientific reader as well as to the specialist.

Perhaps the only suggestion that can be made is that some of the chapters might have been lengthened with advantage; and it is to be hoped that in each succeeding edition it will be enlarged with the results of the author's investigations on the various chemical industries. T.

The Mechanical Engineers' Reference Book for Machine and Boiler Construction. By Nelson Foley and Thomas Pray, Jr. In two parts. Part 1: General Engineering Data. Part 2: Boiler Construction. New York: D. Van Nostrand Co. 1891. Fo. pp. 6 and 148. Draw. 19. Diag. 30.

As a general thing, engineering books of reference have been made as nearly in pocket form as was possible. Where such a form was not feasible by reason of the size of type used, the octavo volumes were about the best for desk use, but now there comes to us a volume measuring 15½ x 12 inches, under the title of *The Mechanical Engineers' Reference Book for Machine and Boiler Construction*, by Nelson Foley, member of the Institution of Naval Architects, of the Institution of Mechanical Engineers, and the Northeast Coast Institution of Engineers and Shipbuilders, assisted by Thomas Pray, Jr., Consulting and Constructing Engineer for Steamships, Locomotive Engines, Stationary Engines and other Machinery; member of American Society of Naval Engineers and various other societies, having residence in Boston, Mass., while Mr. Foley at present is living in Italy.

The book comes from the press of D. Van Nostrand Co., and is printed on good paper in very good type, and has the advantage of what is known as the "ledger index," or notched index on the margin, being in this case what is termed in the trade a "reinforced ledger index," each of the marginal projections that enable the book to be opened at any particular place, being strengthened by muslin as well as paper, the paper being in different colors, beginning with white and running through blue, red and green, separated by others of white.

Upon the margin of the book can be seen at a glance, first: "Measures," then in the next set of pages: "Decimal Equivalents," "Speed Tables," "Thermometers," "Angles," "Surface of Reciprocals," "Logs," "Mensuration," etc., "Sheets per Square Foot," "Sheets and Bars," "Miscellaneous," "Work and Power," "Heat," "Combustion," "Expansion," "Steam," "Statics," "Dynamics," "Electricity," "Strength of Materials," "Elasticity," "Friction," "Flow of Liquids and Gases," "Miscellaneous." In Part 2: "Boilers," "Rules for Scantlings," "Riveting," "Miscellaneous," "Diagrams," "Shells," "Furnaces," "Flat Plates," "Tube Plates," "Girders," "Riveting," "Rivet Length," "Coal," "Drawings."

In addition some slips show merely small wood-cuts, to indicate the subject as two spur gear wheels, two pulleys united by a belt, a small steamship, a turning tool in the act of taking a chip, a pair of scales, and so on.

The book contains 150 pages, besides a large number of drawings and diagrams to scale, enabling one to judge of proportions by a glance at such scales, and giving the advantage of the graphical method of computation.

The author has aimed to simplify and to put into available shape, for instant reference all the most needed matter applicable to ship and engine building up to the present time, and to include the newest engineering data, from practice. The confusion of units applicable to the same requirements has had attention, and an attempt has been made to simplify, as far as possible, what have been considered illy-expressed formulæ, falling back on Rankine in its entirety for his formulæ as far as they would go, and to Regnault for his, omitting a mass of extraneous matter, doing away with confusion from imperfect and careless as well as varying copying.

The graphic computation is understood to be Mr. Foley's, who has been highly commended for his execution of this work by all those who have had an opportunity to use it.

The tables and the graphical part determined the size of the book, and other requirements had to bend to this.

The work on engines, boiler, screw and compound working of steam formulæ has been much modified and brought up to date, at the same time being simplified so far as possible.

It represents a work produced with the editor in Italy, the publisher in London and the assistant editor in the United States; a happy illustration of modern facilities for correspondence.

A careful examination of the pages of this work cannot fail to impress the observer with its utility, and the ready means of reference by the index is particularly convenient. The price of the book is one that will put it beyond the means of some individuals who could use it to advantage, but at the same time it is one of those books that should be in the drawing-room of every machine shop, accessible to the draughtsman and convenient for reference.

Apart from much that is accepted in the literature of mechanics as classical, there are many pages showing the individuality of the author, and much in this respect that is new, while it is all useful.

Since publication a few errors have been discovered as follows:

Page 12, 8″ column at top, change ft. 62 to ft. 62°.

" 53, top right hand, for foot pounds × 7·233 read foot lbs. × ·138.

" 53, top right hand, kilogrammetres × ·138 read kilo. × 7·233.

" 60, near foot reference to page 39, read to page 41.

" 60, next to last example, read 60,081 lbs. not cubic ft.

" 61, near foot reference to pages 52 and 40 should read 54 and 42.

" 92, about one-fourth way down for page 84 read page 83.

" 94, about one-fifth way down for page 84 read 83.

" 115, near top for $V = 5535\sqrt{\dfrac{P^{1\cdot 8} \times P^{\cdot 1} - P_1^{1\cdot 9}}{P^{1\cdot 841}}}$

read $V = 5535\sqrt{\dfrac{P_1^{1\cdot 8} \times P^{1} - P_1^{1\cdot 9}}{P^{1\cdot 841}}}$

Repeated reference to this book during the summer has, on the whole, been satisfactory and useful. It is certainly a valuable addition to the works

of reference in the library of the Franklin Institute, and cannot fail to be appreciated by those members who choose to avail themselves of its excellently arranged matter. C. S.

Calkin's Steam Engine Indicator, New York. The Engineers' Instrument Company. 1891. Pp. 114.

The work is a description of the special forms of apparatus manufactured by this company. The indicator itself differs from those heretofore in common use, in many minor details. The parallel motion is obtained by slotting the top of the piston rod in such a way that the pencil moves proportionally to the movement of the piston. The indicator spring is a single one, and to prevent its tipping and the piston bearing cornerwise on the sides of the cylinder "peculiar manipulation takes place during its manufacture." The method of applying and taking care of the instrument is carefully set forth, and numerous tables and methods of calculation are given, applying equally to all indicator cards, which would aid the user in obtaining all the results desired for the indicator card. The other instruments treated of are the graduated pantograph, polar planimeter, parallel rule, dividing scale, speed indicator, and Calkin's mercurial column for testing gauges, etc.

H. W. S.

PROGRAMME OF LECTURES.

(Season 1891–1892.)

1891.

November 2. Mr. Henry Pettit, "Down the Takaio in Japan" (illustrated by photographs taken by himself).

6. Mr. C. J. Hexamer, "Italy, I" (illustrated).

9. Mr. Henry Pettit, "How the Chinese Differ from Ourselves" (illustrated by photographs taken by himself).

13. Mr. C. J. Hexamer, "Italy, II" (illustrated).

16. Mr. Courtney De Kalb, Mining Engineer, New York, "The Great Amazon: Personal Investigations on the River and its Upper Valley."

20. Prof. Lewis M. Haupt, University of Pennsylvania, "The Port of Philadelphia."

23. Mr. Louis Vossion, Consul of France, "The Khartoum of Gordon's Mission" (illustrated by photographs taken by himself).

27. Mr. Eugene Griffin, Boston, "The Electric Transmission of Power."

30. Prof. J. Howard Gore, Columbian University, Washington, D. C., "How the Earth is Measured."

December 4. Mr. Carl Hering, Electrical Engineer, "Notes on the Frankfort Electrical Exhibition"

December. 7. J. Madison Taylor, M.D., "Physical Exercise: its Relation to Health and Medicine."

11. Mr. William L. Saunders, C.E., New York, "The Compressed Air Power of the Future."

14. Mr. William Kent, Mechanical Engineer, New York, "Some of the Preventable Wastes of Heat in the Generation of Steam."

18. Mr. F. E. Ives and Mr. W. N. Jennings, "The Yellowstone Park" (illustrated with color camera and kodak).

25. Prof. Persifor Frazer, D. Sc., "Christmas Lecture for the Children." 3 o'clock P. M.

1892.

January 4. Prof. Chas. E. Munroe, U. S. Torpedo Station, Newport, R. I., "Transmission of Explosive Phenomena."

8. Hon. Warner Miller, New York, "The Nicaragua Canal."

11. Prof. Wm. C. Day, Swarthmore College, "The Building Stones of the United States."

15. Mr. Alfred E. Hunt, C.E., President Pittsburgh Reduction Company, "Aluminum from an Engineering Standpoint."

18. Prof. G. C. Caldwell, Cornell University, "Oleomargarine."

22. Mr. W. F. Durfee, Mechanical Engineer, "Historical and Constructive Curiosities of Ancient and Modern Mechanism."

25. Prof. S. P. Sadtler, Ph.D., "The Chemistry and Technology of Starch."

29. Dr. L. Webster Fox, "Eyesight: its Care during Adult and Old Age."

February 1. Prof. S. P. Sadtler, Ph.D., "Cellulose, or Wood Fibre."

5. Mr. Edward E. Allen, Principal Pennsylvania Institution for the Instruction of the Blind, "Mechanical Education of the Blind."

8. Mr. H. M. Howe, Mining Engineer, Boston, "Manganese Steel."

February 12. Mr. E. Berliner, Washington, D. C., "Technical Notes on the Gramophone."

15. Mr. Nikola Tesla, New York, "An Experimental Study of Light Effects produced by Alternating High Potentials."

19. Mr. John Hartman, "Notes on the Blast Furnace."

22. ☞ Public Holiday; no Lecture. ☜

26. Prof. D. S. Jacobus, Stevens Institute of Technology, "Experimental Illustrations of the Principles and Properties of Substances applied in Modern Refrigerating Machines."

29. Prof. Edward Orton, Director of the Geological Survey of Ohio, "Petroleum: its Geological History and Use in Modern Civilization."

Franklin Institute.

[*Proceedings of the stated meeting, held Wednesday, Oct. 21, 1891.*]

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, October 21, 1891.

Mr. JOS. M. WILSON, President, in the chair.

Present, 126 members and sixteen visitors.

Additions to membership since last report, twenty-four.

The Secretary presented a memorial of the late Mr. Louis H. Spellier, which was accepted and referred to the Committee on Publications.

Mr. C. M. Lungren, of New York, read a paper descriptive of a new incandescent gas light of his invention, illustrating the same by showing a number of the lights in operation. The light is produced by the incandescence of a thimble-shaped burner, about two inches high and one and one-half inches in diameter at the bottom, formed of interlaced or woven threads composed of the rare earths, thoria, zinconia, etc. These threads have a thickness of about $\frac{14}{100}$ of an inch. The burner is used with fuel gas, or ordinary illuminating gas rendered non-luminous. It is mounted upon a suitable attachment for effecting the proper mixture of gas and air. The burner is intended principally for domestic service.

Mr. Lungren's paper was referred for publication.

Mr. F. Lynwood Garrison followed with some remarks on the progress of the manufacture of tin plate in the United States.

Mr. Swan, of London, England, exhibited a number of specimens of photogravures, made by an improved process of his devising, and gave a brief account of the history of the art leading up to his improvements. The specimens attracted much attention and comment, as being of unusual merit.

The Secretary, in his report, commented unfavorably upon the claims made in behalf of the experiments at present being made under the direction of the Department of Agriculture, for the artificial production of rain by means of explosions of considerable masses of dynamite, etc., in mid-air.

Mr. W. N. Jennings continued the exhibition of his series of local pictures.

Adjourned. WM. H. WAHL, *Secretary.*

JOURNAL

OF THE

FRANKLIN INSTITUTE

OF THE STATE OF PENNSYLVANIA.

FOR THE PROMOTION OF THE MECHANIC ARTS.

VOL. CXXXII. DECEMBER, 1891. No. 6

THE Franklin Institute is not responsible for the statements and opinions advanced by contributors to the *Journal.*

THE HOLMES LUBRICANT BEARING.

[*Report of the Committee on Science and the Arts.*]

[No. 1646.] HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, August 28, 1891.

The Committee on Science and the Arts, constituted by the Franklin Institute of the State of Pennsylvania, to whom was referred, for examination,

PHILIP H. HOLMES' IMPROVED COMPOSITION FOR JOURNAL BEARINGS,

report that this invention aims to furnish a new composition of materials to be used in machinery as journal bearings, packings for sliding surfaces, etc., which possesses the requisite hardness to withstand the usual pressures, and also to offer a surface that, without the aid of oil or other lubricants, will reduce friction to a minimum and preclude the possibility of excessive or dangerous heating.

The principal element of this composition is graphite, reduced to a fine powder and freed as far as possible from all gritty matter.

To render this plastic and cohesive, it is mixed with wet wood pulp, in proportions according with the purpose of the finished article. In this condition the mass is forced into moulds of the desired shape, which latter are provided with ample drainage outlets to permit the escape of the water when the mass is subjected to pressure.

The wood fibre acts as an entangling and straining material to retain the fine graphite and prevent its escape with the water through the perforations of the mould.

After the composition has sustained the requisite pressure in the mould, it is removed and thoroughly dried, then it is immersed in a bath of hot drying oil until saturated, and thereafter baked in an oven until sufficiently hard.

The finished material has thus attained solidity and strength, and when reinforced by metallic support, is capable of withstanding heavy pressure, and becomes a safe and efficient anti-friction bearing for general use.

The uses to which this bearing material may be put are so very extensive, that it is manifestly impossible for your committee to make extensive tests in every direction to prove its efficiency, but so good an exhibit of its application has been afforded us, that safe conclusions may be drawn therefrom regarding its merits, in a range of mechanical uses covering a wide field.

For many valuable data respecting a great variety of tests to which the Holmes composition has been subjected during a period of more than two years, we submit numerous reports, hereto appended,* given by persons of excellent standing and mechanical ability, several of whom are prominent members of the Franklin Institute.

The well-known property of graphite, as a lubricant, has encouraged many attempts to so combine it with other materials, that it might be used as a complete substitute for metal bearings, but up to the present time, no one of

* Appended to the original report, on file, and accessible for reference.

these, save that of Mr. Holmes, has succeeded to the extent of securing even a limited adoption.

All prior inventors have incorporated in their product some unsuitable, and not infrequently some antagonistic material, which, upon trial, has caused the defeat of the object and consequent abandonment of the article.

This, however, does not apply to Mr. Holmes' efforts, for the two chief elements of his composition are both superior anti-friction materials, and the third (drying-oil), while aiding to strongly unite the other two, does not appreciably decrease their anti-friction value. Again, in the Holmes compound there is nothing that any degree of heat that can arise from frictional causes can injure, or by any possibility cause surrounding objects to ignite; therefore, the fire-risk, due to the over-heating of journals, will disappear in direct proportion to the use of these graphite bearings.

We find further that the ratio of friction with the Holmes bearings is much less than with well-oiled metal bearings, and greatly superior to the results obtained in common practice, thereby effecting a great saving in power even in comparison with the most carefully attended metal bearings. The coëfficient of friction of the Holmes bearing is practically constant, being no greater at starting than when running at any speed, which cannot be said of any oiled metal bearing.

This material may be moulded into any desired form with the nicest accuracy of finish, so that all forms may be infinitely duplicated with standard precision, without the necessity of touching a tool to them.

The remarkable qualities of this bearing material are strikingly exhibited in its application to the spinning frame, when the spindles are run at very high velocities. In this direction your committee have taken special pains to verify, by personal tests, the excellent results vouched for by others. Spindles running with unusually tight belts constantly ten hours a day for three weeks, at a speed of 8,400 revolutions per minute, did not heat, or show any perceptible wear either of the spindle or the graphite bearings.

Thus, through Mr. Holmes' invention, it has become

practicable to run an entire spinning plant without using a single oiled bearing, which realizes in economy, cleanliness and freedom from fire risks, conditions of inestimable value. Your committee have also practically tested the brushes made of this material for use upon dynamos, and found them practically indestructible, that they do not wear the commutators, and give most satisfactory results in every way.

Careful inspection of many bearings which have been running constantly throughout the day for several months, show, in no single instance, any appreciable wear either of journal or bearing, which fact is also abundantly testified to by others, whose observations have extended over one and two years in practical tests, showing the durability of these bearings to be very great.

All of the materials used in the Holmes composition are inexpensive, are obtainable in the open market, and their source of supply in the United States is practically inexhaustible.

These facts remove all doubt of the permanency of supply of this composition where its manufacture has once begun, and are also a safe guaranty of successful and economical production.

Your committee are not prepared at this time to set any limit to the usefulness of this graphite bearing, or to express an opinion regarding the ultimate weight per square inch of surface that may safely be applied to it, but are satisfied that the limit, if found at all, will only apply to such bearings as are essential to the very heaviest class of work, and which constitute only a very small part of the immense aggregate of machines and implements to be benefited thereby.

For these considerations we cheerfully accord to Mr. Philip H. Holmes, the inventor of this compound for journal bearings, and of its practical method of manufacture and application, the well-earned credit of having conceived and worked out to a high degree of excellence an improvement of rare importance and very great value, affecting almost the entire system of machinery construction in the

directions of economy of power, extended durability, immunity from fire caused by friction, and extreme cleanliness, and contributing substantially to precision of operation and the increase in quality and quantity of product.

This achievement entitles the inventor to the fullest recognition by the Franklin Institute, and to receive its highest award, the Elliott Cresson Gold Medal, which accordingly is respectfully recommended by the committee.

H. R. Heyl, *Chairman*,
J. Sellers Bancroft,
Thos. P. Conard,
Philip H. Fowler,
Luther L. Cheney,
Stockton Bates,
H. W. Spangler,
S. M. Vauclain.

Adopted, September 2, 1891.

S. Lloyd Wiegand,
Chairman of the Committee on Science and the Arts.

APPENDIX.

[Prof. Coleman Sellers having made a report on the Holmes fibre-graphite lubricant bearings previous to the examination by the Committee on Science and the Arts of the Franklin Institute, which was submitted with other data for the committee's information, the following extracts therefrom may usefully supplement the committee's report.]

* * * *

At your request I visited the exhibition of the Holmes fibre-graphite, as shown at 123 North Fifth Street, Philadelphia. I have carefully looked into the merits of this material.

The object of the invention is to furnish a material of low coëfficient of friction that can be used in machinery without the necessity of oiling, to avoid the inconvenience that arises from oil in some cases, and yet without material loss of power, and without danger of heating, and thereby igniting the surrounding woodwork. It is a well-known fact that many fires in factories have originated from heated bearings, and railroad practice shows daily examples of the ignition of the oil on the journals of car axles, when they have begun to cut and heat.

This material, while capable of being used without oil, is not injured by the application of oil, may be lubricated when the pressure is great, and can be depended on not to cut should the bearing run dry after having been lubricated with oil.

The ingredient made use of by Mr. Holmes is plumbago in a finely-divided condition, and as free from all gritty particles as it is possible to make it. Plumbago as a lubricant has been known for a very long time and many attempts have been made to solidify it in a manner to permit the solidified material being worked and made into the form necessary to answer the purpose of journal bearings or flat sliding surfaces, for all cases where lubrication is resorted to to diminish friction.

The mode of preparation of Holmes' anti-friction material consists essentially in thoroughly mixing it with wood fibre in a moist condition, and pressing the mixed fibre and graphite into a mould of proper form. The compound is of very considerable strength, quite able, if sufficiently reinforced, to bear pressure and capable also of being lubricated if desired, and also capable of running continuously under water as is required in the steps of turbine wheels and other places.

The use of oil as a lubricant in machines is to separate the rubbing parts and to diminish the friction of metal upon metal by an intervening film of the lubricant.

If the oil is furnished in sufficient quantity to cause entire separation of the metals, the friction may be reduced to a measure of the viscidity of the unguent used. Where oil is administered in less quantity, however, the friction of metal upon metal is usually resistance due to interlocking particles of the revolving and stationary parts. The oil used as a lubricant in most cases finds its way from the bearing loaded with the metal that is gradually torn from either the revolving shaft or the box in which it runs.

It is a well-known fact that heavy lubricants effect a better separation for the metals than the finer lubricants, though it is also known that the power required to slide the surfaces one upon the other is much less with the more

limpid lubricant than with the thicker one, but at the same time the wear and tear of the metal may be greater.

For a long time engineers have been seeking for a substance that would be capable of being used as bearing surfaces and have a low coëfficient of friction, either with or without oil. From my several publications on this subject, it will be seen that I have always held to the opinion that if oil can be introduced in sufficient quantity and with sufficient degree of continuity to separate the revolving shaft from the journal bearing in which it revolves, it makes little difference what metal is used for the box; therefore, for ordinary line shafting, I have always advocated the use of cast iron as being the cheapest and most serviceable bearing.

The friction in line shafting varies according to the attention paid to oiling, and many experiments have been tried and the result has been reached pointing towards the necessity of the utmost care in lubrication, and also frequent lubrication to diminish the friction of the bearings.

The experiments I have been able to make with the Holmes material have satisfied me that the cöefficient of friction is lower than that of many oiled bearings in good condition and well attended to. It is undoubtedly lower than with metal bearings as usually operated, with moderate attention and poor qualities of oil. The graphite as compounded will bear lubrication and runs well under water, not being affected by moisture, oil, or by many chemicals, such as acids, ammonia, or any of the chemical substance liable to be found in manufacturing establishments.

It seems to be constant in its frictional resistance when dry under any given pressure, and this quality alone is of importance, as it brings the frictional loss to a constant, while doing away with the cost of oil and the need of personal attention to the moving parts.

It is constant in its small frictional resistance whether warm or cold, while it does not run lighter when warm by use as some oiled bearings do. Its uniform action is better than many oiled bearings and very much safer. The constant amount of frictional resistance being known, can be provided for in the power of the machine.

More than forty years of my life have been spent among machinery and devoted to solving questions involving friction, having contributed no little to bringing line shafting to its present high state of excellence. I have had opportunities to experiment with many kinds of journal-bearings, from glass through the several metals and alloys of metals, to the fluid bearings and modification of oiling devices, as well as the numerous applications of plumbago as a lubricant or the chief component of frictional surfaces. The present composition is new to me and presents advantages that have not obtained with other applications of graphite as a lubricant, that I have tried.

The question of frictional resistance may be considered as a necessary drawback in all mechanical devices, and the best we can do is to reduce this frictional resistance to a minimum, either by presenting as rubbing surfaces materials which slide easily one upon the other, or render motion safe by means of lubricants. The best oils, while dimishing frictional resistance, do not, under ordinary conditions, prevent the wear of metals rubbing one on the other, as is well known by all engineers. It is then, in many cases, a question of how much we can afford to pay for power lost through the use of lubricants that prevent wear of the rubbing parts, or how much wear can be permitted with less loss in the power required to drive the machinery.

The Holmes mixture of graphite gives a substance that can readily be moulded into shape or furnished in timber, roughed to size and capable of being worked into shape with the ordinary tools adapted to cutting wood or metal.

The applications that can be made of this substance with marked advantage extend over all cases of rubbing surfaces. It shows no appreciable wear when running at a surface speed of 1,000 feet per minute and under a pressure of fifty pounds per square inch, and it is generally assumed that when the pressure on rubbing surfaces is less than fifty pounds per square inch, the viscidity of the unguent acts as a sensible retardent. Where the pressure amounts to only a few pounds per square inch on the rubbing sur

faces, the oil acts so much as a retardent as to make it advisable, wherever possible, to dispense with it altogether.

Besides the cost of the lubricant used in a large establishment, with the expectation of diminishing the frictional resistance, there is also the cost of the attention required to apply the lubricant, and to keep the parts clean. Beyond this there are many cases in which the lubricant itself is a source of danger, first as by some kinds of oil coming into contact with wood fibre, or by waste starting fires by spontaneous combustion, and oil also is often injurious to the material that is being worked in the factory.

To dispense with the oil in the case of metal bearings, however, where but little is required, and the speed of the rubbing surfaces is high, involves danger from heating, and many fires originate from hot boxes in factories, as they do continually from the hot boxes under cars on the railroads.

I find the Holmes preparation to be a substance that under light pressures, certainly has a lower frictional equivalent than metal surfaces under the best conditions, lubricated by oils other than of the most costly character. There seems to be, under those conditions, no appreciable wear either of the bearing or the spindle, or other sliding surface working upon this material, even when the velocity is very great, and so far as I have been able to determine, the heat generated by the friction is no greater than we find with many lubricated bearings that are under no greater pressure, but that have as great velocity.

I am unprepared at present to state how far the Holmes composition of graphite can be used under the severe pressures that occur in some cases in machinery, but even in that direction there seems to be a chance for excellent results to be obtained where the material can be prevented from spreading by sufficiently firm surrounding walls.

I have examined with very great attention and care the action of loose pulleys upon shafts, the loose pulley being bushed with this Holmes material. I find that they run freely, do not show wear, give no indication of excessive heat under reasonable conditions of speed, and do away with the annoyance of oil, which, by the revolution of the pulley

is carried out to the revolving ends, and there thrown off and lost. For this one purpose alone the invention is of incalculable value, but the cases in which it can advantageously be applied are so numerous as to include all rapid moving frictional surfaces.

The readiness with which the material can be applied to this use, its good conducting power of electricity and the amount of heat it will bear, open up many uses for it other than as an anti-friction bearing.

If not hampered with too excessive cost charges in its introduction, it presents one of the cheapest forms of self-lubricating material that has yet been made known to me, and the very great saving, as well as the safety incident to its use in dispensing with oil, avoiding danger of fire, and the uncertainty of frictional resistance with lubricants, will make it economical in use, even with a sure profit of very considerable amount to the owners of the invention.

I look upon this as one of the most important improvements that has been made in material for bearings, and likely to work radical and important changes in machine construction. Besides, by its introduction to those applications where the avoidance of oil is desirable, the field of its usefulness would be practically unlimited. Thus where oil is to be avoided from danger of injury to fabrics, to cases where the heat is too great to permit lubrication (such as the axles of cars run into drying ovens), in the case of bearings that are inaccessible on account of situation or danger of approach, in the manufacture of explosives by machinery, etc. Its use in the rapid running of spindles of cotton mills on spinning frames leaves nothing to be desired, while the possible use in draw frames of shell rolls running free without oil, is a strikingly happy application of the invention.

Hinges for heavy doors can be bushed with the material to work noiselessly and freely. Sheaves for window cords, and the sheaves that are inaccessible in dumb-waiters in houses can be so bushed to run freely and without danger.

An invention of this kind, diminishing the use of lubrication, diminishes the cost of machine construction by doing

away with the many devices incident to oil, oil cups, oil hole-covers, the oil holes themselves which have to be drilled and carefully placed, oil tubes to lead the lubricant to the inaccessible parts of machinery, as well as the cost of the personal attention, and the cost of the lubricant required to keep the machinery in working order.

I have carefully considered the statements made by those who have used the Holmes fibre-graphite compound for a comparatively long period and find no exaggerated claims of durability, nor any that are inconsistent with what may be expected from the nature of the substance.

Comparing this substance with the so-called anti-friction metals used to line or cover the bearing surfaces, I find from some experiments of my own, that when emery of the best quality is introduced between a graphite block and a metal plate, the cutting action of the emery is of very short duration as compared to the use of the same emery on the same metal, the rubbing block loaded with emery being made of the best anti-friction metal. These so-called anti-friction metals, hold the emery and the cutting power continues as long as the particles of stone imbedded will last, but when applied to the block of fibre-graphite they seem immediately to become buried in the graphite, and the bearing substance itself furnishes a protection against cutting.

The experiments I have tried in this direction have all been favorable to the Holmes mixture, but one of the most important qualities connected with it is its ability to resist long-continued hammering action. I find that a solid block of the Holmes graphite mixture will bear an amount of hammering that would quite deform the surface of the metals commonly used for bearings.

The ideal bearing surface must be so different in its nature from the metal that slides upon it as to be unable to weld or unite therewith, and at the same time it must, in many cases, be able to bear long-continued vibratory, (called hammering) action, that is incident to unbalanced machinery and much of the services on railroads.

The value of paper stock as a substitute for metal in engineering construction is instanced in the durability of

paper car wheels, hence in a compound of vegetable fibre, intimately mixed with graphite with binding or felting qualities of sufficient power, we cannot but anticipate durability.

The ease with which the Holmes compound can be applied in practice is favorable to its introduction, and I have no reason to doubt the statement made by those who have used it for a considerable length of time and anticipate for it a durability more favorable to the user than to the manufacturer of the material.

Being uninformed as to what the owners propose doing with the invention in the direction of its introduction, I see in it capabilities of numerous producing establishments required to supply the demand that must sooner or later arise, when the good quality of the graphite bearing comes to be known. The application will increase with the means of production, and the saving in cost of its application as compared to anti-friction metal linings that do not dispense with lubrication, is greatly in favor of the graphite.

If this substance, as now seems inevitable, will diminish fire risks, its use will in time be made obligatory in sufficient number of cases to insure its owners a valuable return for what I look upon as a very notable invention.

COLEMAN SELLERS, E.D.,
Consulting Engineer,
Prof. of Mechanics, Franklin Institute,
Prof. Engineering, Proctor Stevens Institute of Technology, etc.

THE DEVELOPMENT OF THE PIG IRON MANUFACTURE IN THE UNITED STATES.*

BY JOHN BIRKINBINE,
President, American Institute of Mining Engineers.

[*Concluded from p. 353.*]

The following remarks concerning the progress of the pig-iron industry and a prophecy as to its future appear in volume xv of the Tenth Census, namely, that of 1880, which is presented here to show how much more rapidly the industry has developed than was then anticipated would be the case six years ago, when it was written.

"In 1866 the United States had reached the production of Great Britain in 1835; that is to say, she was then thirty-one years behind the latter country. At the end of 1884 she was but twenty-one years behind England. And at the same rate of increase for both countries, the United States will be but fifteen years behind England in 1900, and will reach and pass her in 1950, the production of pig iron in each country for that year, as determined from the equation of their respective curves, being a little over 30,000,000 tons."

MR. HEWITT'S ESTIMATE.

In a paper read at a late meeting of the American Institute of Mining Engineers, in October, 1890, by its then President, Hon. Abram S. Hewitt, Table D was presented, showing the comparative rate of increase in population and pig iron production in the United States for six decades.

TABLE D.

Relative Increase of Population and Pig Iron Production.

Year.	*Production of Pig Iron. Gross Tons*	*Rate of Increase. Per Cent.*	*Population.*	*Rate of Increase.*
1830, ...	165,000	—	12,866,020	32·51
1840, ...	315,000	91	17,069,453	33·52
1850, ...	564,000	79	23,191,876	35·83
1860, ...	821,223	46	31,443,321	35·11
1870, ...	1,696,429	106	38,558,371	22·63
1880, ...	3,835,191	126	50,155,783	30·08
1890, ...	9,202,703	140	62,622,250	24·86

* A lecture delivered before the Franklin Institute.

This table, the writer says, "brings out the striking conclusion that the production of pig iron has always increased more rapidly than the population and that the ratio is an increasing one. Between 1830 and 1860, the production of iron increased twice as fast as the population. Between 1860 and 1890 it increased four times as rapidly, in reality over four times, thus proving that the national wealth continues to grow from decade to decade, at a rate of acceleration of which the world affords no previous example. Inasmuch as during all this time, we have imported iron in addition to our production, it follows that the consumption per capita has also increased more rapidly than population. In 1855, according to careful calculations, which I made at that time, we were consuming iron at the rate of 117 pounds per head; whereas, in 1890, the consumption has increased to rather more than 300 pounds per head, the whole of which, for the first time in our history, we are producing within our borders.

Great Britain, on the other hand, produces more iron than it consumes, and is still the largest per capita producer in the world. In 1889, with a production of 9,321,563 tons of 2,000 pounds, and with a population estimated at 38,000,000, the production reached the large figure of 495 pounds per head. Deducting the exports, Great Britain is now consuming 250 pounds per head against a consumption of 144 pounds in 1855. But the production of iron in Great Britain appears to be now very nearly stationary."

Mr. Hewitt anticipates fully as great development of the iron industry as I mention, for he says:

"I think it is safe to estimate, therefore, that in 1900 the world will require 35,000,000 gross tons of iron, of which the United States must supply forty-five per cent., and the other iron-producing countries the remainder, in the proportion of half to Great Britain and half to Germany, France, Belgium and the other smaller producers."

This prophecy means a production in the United States, in the year 1900, of 15,750,000 gross tons.

MR. ATKINSON'S ESTIMATE.

Mr. Edward Atkinson presents the following estimate concerning the prospective demand of the world for pig iron in the year 1900:

	Tons.	*Tons.*
Present production, ...		25,000,000
Increased consumption in the United States, ...	7,000,000	
Increased consumption in Great Britain, France, Germany and Belgium, . .	2,000,000	
Increased consumption in all the rest of the world, ...	6,000,000	
Total increase of demand, . . .		15,000,000
Total supply required, ...		40,000,000

He says: "If then one may predict a continuance of this law of accelerating demand for the next eleven years, neither 40,000,000 nor 44,000,000 gross tons will suffice in the year 1900. If this increasing demand should continue, the supply must be 100 per cent. in excess of that which now prevails. The supply in 1900 must be 50,000,000 gross tons or 56,000,000 net tons. Who will supply it?"

For the reason heretofore given, I do not place the future output at as high a figure as either of the gentlemen named, but at either of the rates of increase indicated, there is an apparently bright future before those engaged in pig iron production, ore and coal mining, coking and other allied industries, who are in position to share in this growth, for every advance made must be with discretion and after a thorough investigation of existing and prospective competition.

The day has passed when iron can be successfully produced without improved appliances, both in construction and modern methods of operation. The blast furnace must supply what the consumer wants, and technical knowledge will keep close company with administrative ability in securing the increased output, to which all investigations point as a certainty.

PRODUCTION OF PIG IRON PER CAPITA.

Referring to the figures for 1860, 1870, 1880 and 1890 (see Table E), it will be interesting to consider the pig iron pro-

duction in the censuses named, and also the population of the country, to show what relations exist between population and production, and taking the figures presented, we find the following relation between the number of people and the tons of pig iron made, in each of the census years, in the several sections of the country, and also in the State of Pennsylvania. Reference is especially made to Pennsylvania, because of its being our own Commonwealth; because it has led, still leads, and will probably continue to lead all other States as a producer of pig iron.

We find that the census year 1860 shows a population of nearly 31,500,000, and a production of less than 1,000,000 tons of pig iron; that is, we produced one ton of pig iron for about every thirty-two inhabitants, but in 1870, while the population had increased about one-quarter, the production of pig iron had been nearly doubled, and in that year one ton of pig iron was produced for every twenty-one inhabitants. The census of 1880 shows a population of over 50,000,000 an increase of nearly one-third over 1870, and a production of pig iron eighty per cent. greater than in 1870. In this year one ton of pig iron was made for every fifteen inhabitants. The census of 1890 shows a population of nearly 62,500,000 and a production of over 8,500,000 gross tons of pig iron. This demonstrates that last year the United States produced one ton of pig iron for every seven and one-third inhabitants.

We may also investigate the distribution of the population and the pig iron production, in each of the four general divisions, following the early method on account of using the census of 1860. These divisions will be New England States, as generally accepted, including Maine and intermediate States to, and including, Connecticut.

The Middle States (New York, New Jersey, Pennsylvania and Delaware).

The Southern States, all States south of the Ohio and Potomac Rivers, and east of the Mississippi River, including Maryland and Louisiana.

The Western States, the rest of the country.

We then find that while the population of New England

increased practically 500,000 souls in each decade, the amount of pig iron produced was varied but slightly, and that this section made one ton of pig iron for every 118 inhabitants in 1860, and one ton for each 156 of its population in 1890.

TABLE E.

Distribution of Population and Production of Pig Iron, According to Census Returns of 1860, 1870, 1880 and 1890.

	1860.			1870.		
	Population.	Production of Pig Iron.	Inhabitants per Ton of Pig Iron.	Population.	Production of Pig Iron.	Inhabitants per Ton of Pig Iron.
United States, ...	31,443,321	987,559	31·84	38,558,371	1,832,876	21·04
Pennsylvania, ...	2,906,215 9·24	580,049 58·74	5·01	3,521,951 9·13	922,564 50·33	3·82
New England, ...	3,135,283 9·97	26,600 2·69	117·87	3,487,924 9·05	30,778 1·68	113·33
Middle States, ...	7,571,201 24·08	706,369 71·53	10·72	8,935,821 23 17	1,171,115 63·89	7·63
Southern States, . . .	9,981,480 31·74	100,761 10·20	89·06	10,859,955 29·16	164,768 8·99	65·91
Western States, . . .	10,755,357 34·21	153,829 15·58	69·92	15,274,671 39·62	466,215 25·44	32·76

	1880.			1890.		
United States, ...	50,155,783	3,375,911	14·86	62,622,250	8,553,374	7·32
Pennsylvania, ...	4,282,891 8·54	1,723,492 51·06	2·48	5,258,014 8·40	4,207,599 49·19	1·25
New England, ...	4,010,529 8·	27,640 ·82	145·10	4,700,745 7·51	30,162 ·35	155·85
Middle States, ...	10,643,486 21·22	2,143,833 63·50	4·96	12,869,293 20·55	4,657,670 54·45	2·76
Southern States, . . .	13,975,686 27·86	311,639 9·23	44·95	16,236,784 25·93	1,582,106 18·50	10·26
Western States, . . .	21,526,032 42·92	892,799 26·45	24·11	28,815,428 46·01	2,283,436 26·70	12·62

The Middle States, with a population of 7,500,000 in 1860, produced over 700,000 tons of pig iron or one ton for every eleven inhabitants, and in the next ten years the population had increased to nearly 9,000,000, while the production of pig iron exceeded 1,000,000 tons, so that

one ton of pig iron was produced for every seven and two-thirds inhabitants. A further increase in population in 1880 to over 10,500,000 and a pig iron output of over 2,000,000 tons, made the production of pig iron one ton for every five inhabitants. In 1890, a still further augmented population to nearly 13,000,000, and a production of nearly 4,750,000 tons of pig iron, was equivalent to one ton to every two and three-quarters inhabitants.

A marked increase is shown in the Southern States which, with a population of 10,000,000 in 1860, produced about 100,000 tons of pig iron, or one ton for every ninety-nine inhabitants; but an increase in the population to 10,750,000 in 1870, was met by an augmented production of pig iron nearly one and two-thirds times what it was ten years before, and one ton was produced for every sixty-six inhabitants; in 1880, the Southern States had a population of nearly 14,000,000, and nearly double the production of pig iron of 1870, so that one ton of pig iron was made for every forty-five inhabitants; in 1890, with a population of over 16,000,000 and a pig iron production of over 1,500,000 tons, the Southern States produced one ton of pig iron for every ten and one-quarter inhabitants.

In the Western States the increase of population has been more rapid, and although the development of the pig iron industry has been greater in amount than in the Southern States, it did not show the same relation per capita. In 1860, the population of the Western States was 10,750,000 inhabitants, and the production over 150,000 tons of pig iron; that is, one ton was produced for every seventy inhabitants; whereas, in 1870, the population was over 15,250,000 and the production nearly 500,000 tons of pig iron, or one ton for every thirty-two and three-quarters inhabitants. In 1880, the 21,500,000 inhabitants and nearly 900,000 tons of pig iron, made the proportion one ton to every twenty-four inhabitants in the Western States, and in 1890, the population was 28,750,000 inhabitants and the production over 2,250,000, or one ton to every twelve and two-thirds inhabitants.

The divisions of the country as given above, do not

properly represent the groupings of the American blast furnaces, and a comparison of the population and pig iron output, made in conformity with existing commercial relations would considerably alter the per capita output in certain sections. However, in the absence of any other generally accepted subdivision of the country, no effort will be made to follow the discussion in detail as to specific localities.

THE POSITION OF PENNSYLVANIA.

The query naturally suggested to Pennsylvanians is, if the United States has in the last thirty years increased its relative production of one ton of pig iron for every thirty-two inhabitants to one ton of pig iron to every seven and one-half inhabitants; and if the Middle States have similarly advanced from one ton to every eleven inhabitants to one ton for every two and one-quarter inhabitants, what has been, and what is, the position of Pennsylvania? Its population of less than 3,000,000 inhabitants in 1860 had increased to 5,250,000 in 1890, while its pig iron product of but little over 500,000 in 1860 was augmented to nearly 4,250,000 in 1890.

In 1860, Pennsylvania produced one ton of pig iron for every five inhabitants; in 1870, it made one ton of pig iron to every three and three-quarters inhabitants; in 1880, one ton was made for every two and one-half inhabitants, and in 1890 one ton for every one and one-quarter inhabitants.

The position of Pennsylvania is more marked when we remember that, according to Mr. James M. Swank, in *Iron in All Ages*, no iron was made in the State prior to 1692, and that was of such small extent that the exact location of the enterprise is not known. As a practical producer of iron, Pennsylvania's history does not commence until 1716, sixty-six years after the establishment of the industry in Massachusetts. It would also be well to note in this connection that until 1859 no pig iron was made in Pittsburgh, and yet in thirty-one years, the magnificent industry in Allegheny County has developed, until in 1890 a total of 1,337,309 gross tons were produced.

Another instance of remarkable development is in Illinois, no iron having been manufactured there until 1839, but in 1890, 701,106 gross tons were produced from fifteen furnaces located in that State.

Allegheny County, Pennsylvania, in which Pittsburgh is located, and Cook County, Illinois, in which Chicago and Joliet are located, are the two greatest producing centres, when compared with the areas covered, that we have in the United States from which reports are published. Their aggregate output was 22 per cent. of the total for 1890.

The Birmingham district of Alabama also represents very rapid development and produces a large amount of pig iron in a limited territory, but as the official statistics are not reported separately from those of the State of Alabama, no absolute statement is offered.

According to the *Iron Age*, the United States during October, 1891, was producing pig iron at the rate of 9,750,000 gross tons annually, and in commenting upon the contributors to this output, the following editorial statement is made: "The product of one great steel company, the Illinois Steel Company, was during the month of October nearly equal to that of all the coke furnaces in Alabama, Tennessee and Georgia put together, the aggregate in each case being a few hundred over 100,000 gross tons. The Carnegie firms, in Allegheny County, made about 82,000 tons in the same month."

A review of the above memoranda demonstrates the following:

In 1860, the production of pig iron in Pennsylvania per capita was nearly as great as that of the Middle States in 1880, twice that of the Southern States in 1890, and two and one-half times that of the Western States in 1890.

The per capita output of pig iron in the United States is now considerably less than that of Pennsylvania thirty years ago.

In three decades, the output of pig iron per capita in Pennsylvania has quadrupled, and that of the rest of the United States, in the same time, has not kept pace with the Keystone State; although the Western States show a some-

what accelerated growth of output per inhabitant, and the Southern States a remarkable increase in this particular. The oft prophesied annihilation of the blast furnaces of Pennsylvania and their removal to other localities, seems no nearer fulfilment than it was years ago.

Taking the production of pig iron in the United States in the future at one ton for each six inhabitants, (say) 375 pounds per capita annually, the Western States must double their output of pig iron and the Southern States increase their production fifty per cent. before they supply the requirements of their present population, if that population represents average consumers.

If Pennsylvania should not augment its annual output of pig iron one ton in the next decade, she would still, in all probability, head the list of producers, and contribute about one-third of the supply of the nation. With a wealth of fuel, ore and flux, with excellent transportation facilities to convey fuel, distant ores to, and the product from, the furnaces, and with a strong home market, the iron masters of the Keystone State are not in need of sympathy from prophets of evil; and only as the other sections of the country exceed the national per capita production, will inroads be made on the State's natural market; unless these sections fail to foster a development which makes the people consumers as well as producers.

I may be pardoned for calling attention to the words of the prophet, "Shall iron break the Northern iron and the steel," (Jeremiah xv: 12), as a question still unanswered affirmatively for the pig iron industry of the United States.

THE FUTURE SITUS.

A late publication, by Mr. Edward Atkinson, *The Future Situs of the Principal Iron Production of the World*, from which an excerpt was given concerning the probable output of pig iron in 1900, contains the following cautious prophecy as to "the future situs of the iron production of the world:"

"One may not venture yet to name the specific place or places. The survival of the fittest among the many enterprises now claiming public attention will soon determine it

in the emulation between the North, the South and the West.

"Suffice it that if one should stand upon the top of the highest peak among the Great Smoky Mountains in the heart of the Southern Appalachian chain, and could bring within his vison all that would come within a radius of seventy-five to 100 miles, he might be able to establish the centre of iron and steel production which would not be very far away from what has been called the 'centre of gravity' of the population of this country.

"If he could bring within his vision the whole configuration of the area enclosed within a circle of about 150 miles in diameter, centring on the Great Smoky Mountains, he might trace the lines made by the erosion of the rivers and the gaps in the ranges on which the rails may be laid to the northwest at the southern border of Ohio, and to the southeast on the way toward the Atlantic ports of South Carolina, over which the metal produced at the possible future centre of the iron production of this country may be distributed on the easiest grades, either for domestic consumption or for the supply of foreign markets."

The region referred to is known to abound in minerals suitable for conversion into pig iron and its stores of hidden wealth are probably much greater than is now recognized. But if American pig iron producers could be carried to the peak of the mountains referred to, and be shown all the wealth of the little world of from 40,000 to 80,000 square miles area, even this will hardly tempt them to believe, as far as the United States is concerned, the prophecy, which the text of the paper indicates, was made as much to formulate an argument against the present customs duties as to determine a situs.

To agree with Mr. Atkinson, we must assume that the development of the ores of the Eastern and Middle States have reached their maximum, that the great coal areas of Pennsylvania, Ohio, Indiana and Illinois are to see comparatively little future extension in mining operations for metallurgical uses, that the wonderful supply of iron ores of Michigan, Wisconsin and Minnesota, which in 1890 amounted

to over 9,000,000 gross tons, or more than half of what the entire country furnished, are to make but small advances in utilization; that the ores of Southern Missouri, Arkansas and Texas, and the coals near the border of Indian Territory, if developed, are not to be assembled in quantity sufficient for a large producing industry.

In addition, we must make no allowance for the exploitation of the excellent ore deposits of Wyoming, which are distant from Chicago less than fifty per cent. farther than where the present ore supply for furnaces near that city is obtained. We must give Colorado small margin for augmenting its iron industry, and omit serious consideration of utilizing the known minerals of Utah, and we must also leave out of our calculation the possibility of the Pacific States employing their recognized mineral resources on a liberal scale.

To accept Mr. Atkinson's situs, we must dismiss the illusion that the market is a most potent factor in the establishment of an iron industry, an *illusion* (?) that has caused capital to embark in iron production and manufacture at points like Chicago, where none of the raw materials are indigenous, but where they can be assembled advantageously and where unusual market facilities are offered.

If we endorse his conclusions as correct, we must question the business foresight of the Pennsylvania Steel Company, erecting large works near Baltimore, to which fuel must be carried over 200 miles and ores brought from Cuba, and also doubt the wisdom of the additions to the iron and steel works at and near Pittsburgh and Chicago. In short, we must assume that those most intimately associated with the pig iron industry have given no thought to its future.

Mr. Atkinson apparently treats of the future solely in the light of the past, without making due allowance for possible and probable advances in mining, preparing and transporting fuel, ores, etc., in modifying present practice or processes, or in utilizing waste materials. The next quarter of a century may show improvements which would surprise us as much as the output of some of our mines or furnaces or the

present use of compressed air, electric light and gaseous fuel would have done twenty-five years ago.

The iron industries of Pennsylvania are here to stay, the ores of New York and of the Lake Superior region will continue to be in great demand, the South and the West will add to their industries; Canada, too, will develop her resources, iron production and manufacture will extend beyond the Continental divide and follow the tide of population rather then congregate in a limited area of mineral development. In this, the localities indicated by Mr. Atkinson will share, and possibly share liberally, but allowing for a considerable export trade, it is probable that the future situs of iron production of the United States will be considerably removed from the point indicated and that of the world still further from the highest peak of the Great Smoky Mountains.

FUEL GAS: ITS PRODUCTION AND DISTRIBUTION.

By Arthur Kitson.

[*A paper read before the Franklin Institute, February 18, 1891.*]

Fuel gas is not quite so recent a discovery as many people suppose. Half a century ago, M. Ebelmen described, in a paper read before the French Academy of Sciences, a method for utilizing charcoal *débris*, coal slack, and other carbonaceous refuse, by converting them into the form of gaseous fuel, which was conveyed to suitable furnaces, and there consumed. This process was operated with considerable success at the iron forges of Audincourt. Ebelmen's method formed the basis of nearly all the fuel gas systems that have since been produced, and consisted in the partial combustion of carbon by forcing a limited supply of air or a mixture of air and steam into a furnace containing the solid fuel in a state of combustion. The gaseous products resulting from the gasification of charcoal by a blast of hot air consisted of—

		By Volume.	
Combustible, . . .	Carbonic Oxide (CO)	= 33·3	36·1 per cent.
	Hydrogen (H)	= 2·8	
Non-combustible, .	Nitrogen (N)	= 63·4	63·9 per cent.
	Carbonic Acid (CO_2)	= 0·5	
		100·00	

and with a mixture of air and steam the products were—

		Percentage.	
Combustible, ...	CO	= 27·2	41·2 per cent.
	H	= 14·0	
Non-combustible, ...	N	= 53·3	58·8 per cent.
	CO_2	= 5·5	
		100·00	

Twenty years later the Siemens regenerative furnace was introduced, and the startling results achieved by its inventor in metallurgical work rapidly opened a wide field for the use of fuel gas in the iron and steel industries. It was demonstrated that seven hundredweight of coal would do the same work that had hitherto been performed with a consumption of at least two tons of coke in heating one ton of iron to welding heat; and twelve hundredweight of coal replaced three tons in melting one ton of steel by means of this gas furnace. The success of fuel gas for metallurgical work was at once assured.

Until the supply of natural gas in Pittsburgh had created a demand among domestic consumers for this desirable addition to modern household conveniences, there had been scarcely any attempt to provide private dwellings with any other than illuminating gas. It is true that some attempt was made in Germany to introduce a heating gas, and that as long ago as 1862, a company was formed in Birmingham, England, to supply that city with fuel gas at a cost of sixpence per 1,000 cubic feet. This bill was actually presented to Parliament, but thrown out in Committee of the House of Lords, because their lordships thought that if the scheme was as good as represented by its promoters existing gas companies would gladly engage therein. It is needless to say that the existing gas companies, already possessing the lighting monopoly of cities, did not care to

undertake any experiments nor embark in fresh schemes, and it was reserved for an individual twenty-five years later to put the first fuel gas plant in operation for domestic purposes. In this country progress has been more rapid, owing, undoubtedly, to the presence of natural gas. The great boon that the discovery and use of this gas has been to certain portions of the West, resulting in the foundation and growth of large and prosperous towns—a discovery that has brought health and happiness to thousands, besides enriching those districts where it exists to the extent of millions of dollars, has excited a demand for an artificial substitute where natural gas does not exist that must sooner or later be supplied. Moreover, the long-predicted exhaustion of natural gas in those regions where lately it was most abundant seems nearing realization, as foreshadowed by the recent action of the Pittsburgh companies in cutting off all supplies for industrial uses and confining themselves to domestic consumers. Such districts cannot well go back to their old habit of burning coal direct. A substitute for natural gas is inevitable.

The distinction that is made between fuel gas and illuminating gas arises chiefly from the difference in cost. Illuminating gas makes an excellent fuel gas, providing it can be sold at a price sufficiently low to allow of its use for fuel. In thousands of instances, both coal gas and carburetted water gas are used in cooking and heating stoves, but their uses as fuel are limited, owing to the cost of such heat. Fuel gas necessarily means cheap gas, and in order to take the place of solid fuel, it should not exceed the cost of coal at the place of consumption. Now, since the combustible gases generated from coal, whether by the process of distillation—as in the ordinary coal gas system—or by the conversion of the carbon into carbon monoxide, with the addition of hydrogen from decomposed steam—as in the water gas system—contain less energy than that from which the gases are obtained, it would appear, at first sight, impossible to replace coal by its gases, economically speaking; but when we reflect that out of possibly 29,000,000 units of potential heat contained in a ton of coal, we

derive, in ordinary domestic uses, scarcely perhaps 5,000,000; whereas from thirty to fifty per cent. of the total heat of combustion of gas is readily available, it becomes evident that we can afford a good margin of loss for the conversion of coal into gas, and still achieve better results than with the coal itself. The saving of space occupied for coal storage, and all the expense and trouble incident to handling coal and removing ashes, to say nothing of the cleanliness and healthfulness, are points of sufficient advantage to give to fuel gas a superiority, if even the economy were no greater than with coal. I do not mean to say that it is cheaper in all cases to convert coal into gas, and burn the gas, than to use the coal direct. There are uses to which coal burned directly is the cheaper system. Such, I believe, is at present the case with the modern steam boilers, where combustion is, in able hands, nearly perfect, and the products escape at a temperature not exceeding 500° F.

In order to ascertain the cost of a gas, we must know, first, its composition; second, the purpose for which it is to be used; and, lastly, the price per unit of volume. Its composition gives us both its heating value and flame temperature. Having given the use to which it is to be applied, we may judge of the quantity we must consume to produce a given effect. Finally, its price per 1,000 cubic feet enables us to figure the cost at which we can do our work.

It may be useful at this point to call attention to the distinction between the calorific value of a gas and its calorific intensity. There is a great deal of misapprehension prevalent on this subject. If we wish to select a gas for heating a substance to incandescence, a Welsbach burner, or Fahnehjelm comb, for instance, we need a flame of high calorific intensity, and should choose uncarburetted water gas. If, on the other hand, we wish to boil water, we should choose natural gas, and next to that coal gas. Of course, this supposes no difference in their cost. The calorific value of a gas is the sum total of the heat units contained in its combustible constituents, irrespective of the diluents associated therewith, *i. e.*, heat units per unit of volume

Calorific intensity is dependent, not alone on the thermal units contained in the gas, but varies inversely with the weight of the resultant products of combustion of the gas multiplied into their specific heat.

Of all artificial substitutes for natural gas, that commonly known as water gas is by far the most popular, and claims the greatest number of advocates.

Water gas is made, as most of you are aware, by forcing steam through a deep body of incandescent coal or coke. This action is alternated with that of blasting air through the fuel to regain the necessary temperature of combustion preparatory to again driving in steam.

The steam is decomposed in presence of the incandescent carbon, forming carbon monoxide, the hydrogen of the steam remaining free. These two gases, H and CO, are given off in about equal quantities, and burn with a beautiful pale blue flame. The chemical transformation is conveniently represented by the equation $C + H_2O = CO + H_2$. This, however, is not the precise manner in which the transformations occur. Carbonic acid gas is first formed and is converted into carbon monoxide in presence of more carbon. It is exactly represented thus: $4\ H_2O + 4\ C = 8\ H + 2\ CO_2 + 2\ C = 8\ H + 4\ CO$.

Coal gas, that made by the retort system, has also its advocates as a fuel gas, but hitherto there has been no practical demonstration of its production at a price calculated to ensure its use as a fuel to any great extent. The returns from its manufacture and supply are based largely upon the sale of the bye-products, coke, tar, naphthaline, ammoniacal liquor, etc., and the profits are, therefore, dependent upon fluctuating markets for these products, as well as the price of the gas. This system pertains, therefore, rather more to what is commonly known as the chemical, than to the gas industry.

It has been proposed to convert the bye-products, coke and tar, into gas and mix with the distilled gases; but this virtually brings the system within the class of water gas systems, since the solid fuel, coke, would be treated by the ordinary water gas process. Moreover, it is quite possible

to carry on the process of distillation, and the water gas process in one and the same generator, and so avoid the extra labor and expense which the retort system entails.

WATER GAS—SEMI-WATER GAS—PRODUCER GAS.

Let us now investigate the methods described for gasifying coal for fuel purposes, in order to ascertain in what way we are likely to achieve the best results. We may conveniently divide them into the three classes, viz: water gas, semi-water gas and producer gas. The first is known as the alternate system, in contradistinction to the last two methods which are continuous.

Taking the first method described by Ebelmen of gasifying carbon, viz: forcing a blast of air through a deep bed of the ignited fuel (producer gas), you will see by the table above given we get only about thirty-five per cent. of combustible gases. If we could eliminate the nitrogen from the atmosphere by a cheap and simple process, and supply oxygen alone and in the requisite quantity to convert all of the carbon into carbonic oxide, we should get from one ton of anthracite of 2,240 pounds, 4,666 pounds, or nearly 60,000 cubic feet of this gas, containing 20,200,000 heat units. The coal itself would possess almost one-third more heat units than this, *i. e.*, 29,000,000, if we allow 240 pounds of the ton as ash. Apparently, there is here a decided loss in converting coal into gas. The loss is, of course, due to the partial combustion which takes place when one atom of oxygen unites with one of carbon, carbonic oxide being the product. In other words, if we convert the carbon at once to its final product, carbonic acid (CO_2) from one pound of carbon so consumed, 14,500 heat units are evolved; whereas, if we turn the carbon first into carbonic oxide (CO), we evolve from the same pound of carbon 4,400 heat units, obtaining 233 pounds of CO; and this, when burned, evolves only 10,092 units, so that the 4,400 units appear to be lost.

What becomes of this heat we call lost? It is generated in the furnace, and whilst some of it is radiated through the sides, most of it is carried off by the gas, which leaves the furnace at a high temperature. If, therefore, we use the

gas in its heated condition as it is generated, we shall lose, approximately, only that quantity lost in the furnace itself. We should obtain the 20,000,000 heat units from the actual combustion of the gas, and probably 7,000,000 units more of sensible heat. Now, the effect of the nitrogen—the presence of which we cannot avoid, if we use air—is, not to lessen the total quantity of the carbonic oxide producible, but to lower the temperature of the furnace. The weight and volume of gaseous products being greatly increased, the heat is spent over a larger volume, and the temperature is necessarily reduced. Of course, a given volume is less combustible than when the nitrogen is absent. In this case we obtain 170,000 cubic feet of gaseous products, 110,000 feet of which is inert nitrogen. What would be the temperatures of the furnace where the nitrogen is present and where absent? In the one case, the furnace heat would be

$$\frac{2{,}000 \times 4{,}400}{4{,}666 \times \cdot 2479} = 7{,}600^\circ \text{ F.}$$

In the other,

$$\frac{2{,}000 \times 4{,}400}{(4{,}666 \times \cdot 2479) + (8{,}664 \times \cdot 244)} = 2{,}685^\circ \text{ F.}$$

By "furnace heat" we mean the average temperature existing in the furnace. In practice, we have really a gradually descending degree of temperature from the zone of combustion to the zone of distillation—where the gases leave the furnace. The zone of combustion exists where the air is supplied to the fuel. In this region active combustion ensues, and the carbon is converted into carbonic acid gas, per saltum. In passing through the superincumbent coal, the carbonic acid gas gives off part of its sensible heat to the coal, and at the same time undergoes a transformation by losing an atom of oxygen, which unites with the free carbon, and is thus converted into carbonic oxide (expressed by the equation $CO_2 + C = 2CO$). That portion of the furnace in which this chemical transformation occurs we term the zone of carbonization. This change entails a further loss of heat.

In passing out at the top of the furnace, the gas imparts a

further quantity of sensible heat to the top layers of fresh unconsumed coal, and carries off the moisture in the form of steam. There is, therefore, a gradually diminishing furnace heat from the zone of combustion, (say) 2,500° to 3,000° F. down to probably from 1,000° to 1,500° at the take-off pipe.

Now, if the gas has to be stored for any length of time, or conveyed long distances through cold pipes, a very severe loss is necessarily entailed. For instance, in burning the gas produced from a ton of coal, at atmospheric temperature, we should lose an amount of heat equal to from 4,000,000 to 7,000,000 heat units. This would prove a serious loss, and in order to avail ourselves of a portion of this thermic capital, we must burn the gas as it issues from the gas furnace without permitting it to cool.

As most of you are aware, the feature of Siemens regenerative furnace consists in the utilization of this sensible heat. We are now in a position to understand the advantage of using steam mixed with the air and see how it is made available. Steam enables us to lower the furnace temperature, and consequently reduce the sensible heat of the gases, at the same time conserving the thermal energy for future use. By injecting a mixture of steam and air, we require less air than where it is used alone, since the steam provides a certain quantity of the oxygen necessary to convert the carbon into carbon monoxide. The air maintains the furnace temperature essential for decomposing the steam in the presence of the red-hot coal; the oxygen of the steam unites with the coal to form carbon monoxide (CO), and the hydrogen remains free. You will, therefore, see the enormous advantage the use of steam thus affords. Instead of free nitrogen, we get free hydrogen, which is not only a highly heating and combustible gas, but exceedingly light, and confers low specific gravity to the gaseous products with which it is associated—a feature of considerable advantage where the gases have to be carried some distance before burning. Of course, the use of steam entails a consumption of the heat energy of the furnace, and it becomes a rather nice point to so proportion the steam and air that

the fuel can maintain sufficient heat to carry on the chemical transformation of the steam to combustible gases, and reduce, at the same time, the quantity of air to a minimum. The less the amount of air used, the less the proportion of inert nitrogen in our fuel gas—a point to be aimed at; and the greater the proportion of steam the greater will be the heating power of our gas, providing always the requisite furnace heat be maintained to decompose the steam effectively.

If we ascertain the heat generated in the furnace, and that expended in effecting the chemical transformation of a given weight of steam into combustible gases, the furnace temperature can be known, and this will guide us in determining what amount of steam may be used with success.

Having given the following data, let us calculate the results:

Eight hundred pounds steam supplied from a boiler at 300° F.; 2,240 pounds anthracite or coke, containing 240 pounds ash; 10,013 pounds of air. We will allow for a loss of twenty per cent. of steam that will, in all probability, escape decomposition in the furnace; also, ten per cent. of carbon burned to CO_2.

HEAT PRODUCTION.

		B.T.U.
1,800 pounds of carbon burned to CO	= 1,800 × 4,400 =	7,920,000
200 pounds of carbon burned to CO_2 =	200 × 14,500 =	2,900,000
Heat carried in by steam, 800 × 300° × ·475	=	114,000
		10,934,000

HEAT EXPENDED.

Allow twenty per cent. of steam as wasted in escaping through furnace without undergoing decomposition:

	B.T.U.
160 pounds heated from 300° F. to (say) 1,300° F.	
160 × 1,000 × ·475 . . . . . =	76,000
Conversion of 640 pounds of steam at 300° F.	
$\frac{640}{9}$ × 53,900 . . . . . =	3,832,290
Allow ten per cent. loss in furnace by radiation, etc, . =	1,093,400
	5,001,690

Then, 10,934,000 — 5,001,690 = 5,932,310 heat units contained in the furnace.

Our furnace heat is determined as follows:

CO_2, ...	= 732 pounds × 0·2164 =	158·405
CO, ...	= 4,194 pounds × 0·248 =	1,040·212
N, ...	= 7,660 pounds × 0·244 =	1,869·040
H, ...	= 71·11 pounds × 3·4046 =	241·774
	12,657·11	3,309·431

and

$$\frac{3,309·431}{12,657·11} = ·261$$

being the average specific heat; and

$$\frac{5,932,310}{12,657·11 \times ·261} = 1,800° \text{ F.}$$

being the average furnace heat.

The proportion of gases by volume will be as follows:

H, ...	12,700	Combustible, about 39 per cent.
CO, ...	53,700	
CO_2, ...	6,000	Non-combustible, 61 per cent.
N, ...	97,900	
	170,300 cubic feet.	

Now, this temperature is much higher than is necessary for decomposing steam, and shows that' our proportion of steam to air is too small for economical work. We may, therefore, increase the weight of steam with advantage.

Let us increase the weight of steam one-third, making it 1,200 pounds. We have then—

	Pounds.
Coal, ...	2,240
Carbon, ...	2,000
Steam, ...	1,200
Air, ...	8,810

In these tables I have not allowed for an excess of air, which is, of course, essential in practice, and which will somewhat modify the results theoretically obtained.

HEAT PRODUCED.

		B.T.U.
1,800 pounds (C to CO)	= 1,800 × 4,400	= 7,920,000
200 pounds (C to CO_2)	= 200 × 14,500	= 2,900,000
Heat carried in by steam	1,200 × 300° × ·475	= 171,000
		10,991,000

HEAT EXPENDED.

	B.T.U.
20 per cent. escaped steam, 240° × 800 pounds × ·485 =	91,200
Conversion of 960 pounds steam, $\frac{960}{9}$ × 53,900 . . . =	5,748,900
10 per cent. loss by radiation . . . . . =	1,099,100
	6,939,200

Then, 10,991,000 — 6,939,200 = 4,051,800 heat units in the furnace.

Then to ascertain the furnace temperature:

CO_2 =	733	pounds × 0·2164 . . . . . =	158·621
CO =	4,194	pounds × 0·2479 . . . . . =	1,040·212
N =	6,740	pounds × 0·244 . . . . . =	1,644·560
H =	106·66	pounds × 3·4046 . . . . . =	362·644
	11,773·66		3,206·037

Then

$$\frac{3,206·037}{11,773·66} = ·272$$

the average specific heat, and

$$\frac{4,051,800}{11,744 \times ·2723} = 1,280° \text{ F.}$$

being the average furnace heat.

The amounts of the gaseous products by volume in this case are:

		Cubic Feet.	
Combustible, ...	H, ...	= 19,000	44 per cent.
	CO	= 53,700	
Non-combustible, . . .	CO_2, ...	= 6,000	56 per cent.
	N, ...	= 85,800	
		164,500	

The total heat units are as follows:

	B.T.U.
H = 106·66 pounds × 62,000 . . . . . =	6,612,920
CO = 4,194 pounds × 4,325 . . . . . =	18,139,050
	24,751,970

and

$$\frac{24,751,970}{164,500} = 151 \text{ B.H.U.}$$

per cubic foot, which is nearly one-half the value of uncarburetted water gas.

Are these results the best attainable? I think not. In a properly constructed furnace we ought to be able to obtain and maintain fifty per cent. of combustible gases from the total products. With care we can work at a lower temperature than that last obtained, because experience shows that the gases do not leave at furnace heat.

Supposing they leave at 800° F., then the furnace temperature is increased:

$$\frac{480 \times \cdot 272}{\cdot 22} = 589° \text{ F.}$$

the temperature becoming 1,869° F.

A large percentage of the heat ordinarily lost through the brickwork, as well as the sensible heat of the products themselves, may be utilized by heating the steam and air before they enter the furnace.

Of course, these calculations are based on theoretically perfect combustion, and no excess of air has been allowed.

Under the best conditions it is possible to decompose 1,500 pounds of steam to every ton of coal, providing the steam is furnished from an independent source, and to obtain approximately the following results:

		Weight. Pounds.	*Volume.*	*Heat Units.*
Combustible, . . .	Hydrogen, . . .	1,666	29,800	10,333,292
	Carbonic oxide, .	4,194	53,700	18,139,050
Non-combustible, .	Nitrogen, ...	5,179	65,500	—
	Carbonic acid, .	733	6,000	—
		10,272	155,000	28,472,342

This equals nearly fifty-four per cent. combustible products and gives 183 heat units to the cubic foot. Can this quality be generated continuously? Experience shows that it can, providing the steam and air are supplied at a sufficiently high temperature. With steam furnished from a separate boiler, at (say) 500° F., no difficulty will be found in producing this quality of gas.

There is still the fuel requisite for supplying the steam to be calculated and allowed for in these results. To produce 1,500 pounds of steam from water at atmospheric temperature and raise it to 500° would necessitate a consump-

tion of from one-eighth to one-quarter ton of coal; so that our results are reduced to 130,000 cubic feet of gas, containing 183 heat units to the foot, or 23,500,000 heat units to the ton of coal.

The question naturally arises whether it is possible to generate the steam in the same furnace and still maintain the quality of gas.

To do this we have only the waste heat of the furnace, *i. e.*, the sensible heat carried off by the gaseous products, and that radiated through the brickwork, to work with, since we cannot lower the temperature of the furnace without seriously affecting the quality of the gas. As shown, we need 2,500,000 B. T. U.

Suppose the gases leave the generator at 500° F. above the atmosphere. There are 10,250 pounds $\times$ 600° $\times$ ·272 = 1,660,000 B. T. U. carried away by the gaseous products from one ton of fuel, and allowing ten per cent. loss for radiation, etc., 1,090,000, making a total of about 2,750,000 heat units.

If it were practicable to utilize entirely this waste heat in producing and superheating the steam, the perfection of the gasification of coal would be reached, for there would be contained in the combustion of the gases ninety-five per cent. of the heat units contained in the coal itself. By placing a superheater in the take-off pipe, and a superheating coil in the brickwork, a considerable amount of this waste heat becomes available.

Allowing for all contingencies, I believe it is possible to obtain from 2,240 pounds of anthracite from 150,000 to 160,000 cubic feet of semi-water gas, averaging 165 heat units to the foot, which will contain 25,000,000 units of potential heat, or about eighty-three per cent. of the heat energy of the coal itself.

This system possesses, in my judgment, the best solution of the fuel gas question. The cost of its production is trifling, and the labor attached to its manufacture (usually a considerable element in the cost of gas) very slight.

With coal at $3 per ton, its cost of production should not exceed two and one-half cents per 1,000 cubic feet. In other

words, we ought to obtain 1,000,000 heat units at a cost of fifteen cents. At the present price of Philadelphia city gas this same quantity of heat costs $2.30!!

The objections that are urged against the use of gas of this quality are: (1) That the presence of so much inert matter necessitates the use of larger pipes, and (2) that combustion is maintained with difficulty. The first of these objections only applies where it is absolutely necessary to use the pipes already existing and hitherto used for illuminating gas. If new pipes have to be laid it is not so great an undertaking to lay a nine-inch pipe, instead of a six-inch, for instance, and should not prove a serious obstacle.

But the same objection would hold good as against water gas. Water gas contains only one-third the heating value of natural gas and one-half that of coal gas; and if a certain sized pipe were just sufficient to carry natural or coal gas, it would be too small for water gas unless the pressure were considerably increased, and this would necessitate better laid mains and better joints than we are now accustomed to.

When gas becomes generally used for fuel, no such sizes of mains as those now used for the supply of illuminating gas will furnish anything like the demand.

Moreover, in the method of distribution that I will presently describe, this objection vanishes.

The question becomes a mere arithmetical problem: Does the interest on the investment required to provide larger mains equal, exceed, or is it less than the value of the extra heat units supplied?

This is a simple problem and its solution is an answer to this question. It is merely a question of dollars and cents.

The other objection urged is that that there is difficulty in maintaining combustion. This objection is confined almost entirely to the gas known as producer gas, that made in blasting the furnace in the water gas process, in which the combustible products do not exceed thirty-five per cent. With the gas I have described, combustion is readily maintained, especially when it is heated prior to ignition, a condition easily obtained for all ordinary purposes.

Water gas, made by what is known as the alternate method, consisting in alternating the steam and air blast, will furnish under the best conditions not more than 40,000 cubic feet of gas, containing 300 heat units per foot, a total of 12,000,000 to the ton of coal. It is composed of carbon monoxide and hydrogen, almost entirely. The producer gas—that given off in blasting the furnace with air—is of too little heating value to convey long distances, and must be burned in large quantities to be effective. It is advantageous to burn this under the boilers for furnishing steam.

The thermal intensity of water gas is very high, whilst its calorific value is less than half that of coal gas. Its success as a fuel depends solely on one point, the cost of distribution. It can be produced cheaply enough to warrant its introduction, but, unfortunately, the expense incurred in getting it from the holder to the consumer is generally greater than that of manufacturing and putting it into the holder. It is already in use for fuel in several cities, and is sold, I understand, at forty and fifty cents per 1,000 feet. Fifty cents is too much. Coal gas at $1.25—the price charged in New York City—is just as cheap for ordinary domestic purposes. To compete successfully with coal, water gas containing 300 heat units to the foot should be sold at twenty cents per 1,000, at which price there will be no difficulty in selling all that a company can produce in every city, except where natural gas is already supplied.

To recapitulate: Of the three methods for converting coal into gas for fuel, viz: by natural or forced draught without steam, by forced draught with steam, and by steam and air alternately—resulting in the generation of producer gas, semi-water gas and water gas, respectively—semi-water gas contains eighty to eighty-five per cent. of the heating value of coal, and is the cheapest gas if supplied within a reasonable distance from the place of production.

Producer gas must be burned hot as it issues from the producer, to be advantageous. Water gas contains only about two-fifths of the heating value of the coal from which it is produced, and is, *per se*, the most expensive of the three systems.

The accompanying diagram (*Fig. 1*) represents these three gases proportionately by volume, and with their constituents.

FIG. 1.

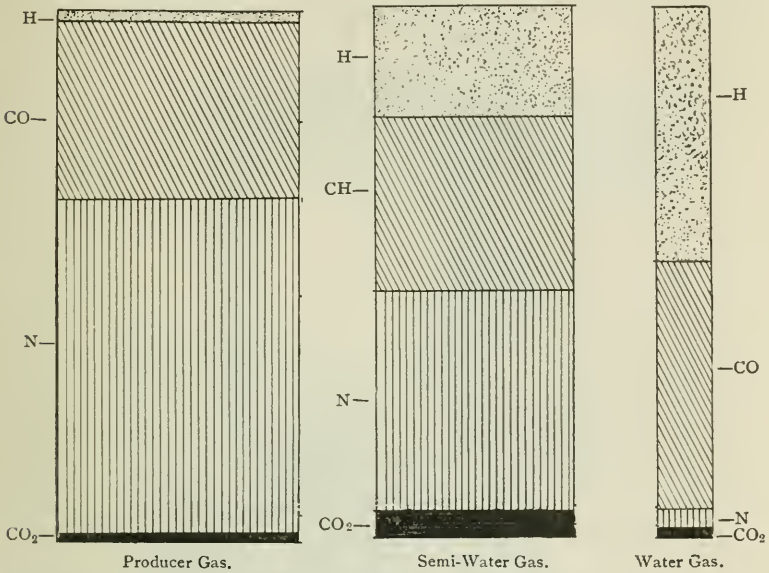

Diagram showing comparative amounts of the various constituents of producer gas, semi-water gas and water gas from a ton of anthracite.

Not the least of the advantages which semi-water gas, or "steam-jet" producer gas, as it is sometimes called, possesses over water or coal gas, is the ease and simplicity of its production. It can be made in a furnace not much larger than some that are in use for heating dwellings, it requires no storage, is automatic in its production, and can be made in quantities varying from 500 cubic feet to an indefinite quantity per hour.

DESCRIPTION OF KITSON'S GAS PRODUCER.

In compliance with the request with which your Secretary honored me, I will briefly describe the apparatus I have designed for the manufacture of semi-water gas, and am now using in connection with the Körting gas engine for the production of power. This furnace has been in use for some time driving the gas engine, which sup-

plies power to a dynamo, and this in turn charges a storage battery. The battery furnishes current for a

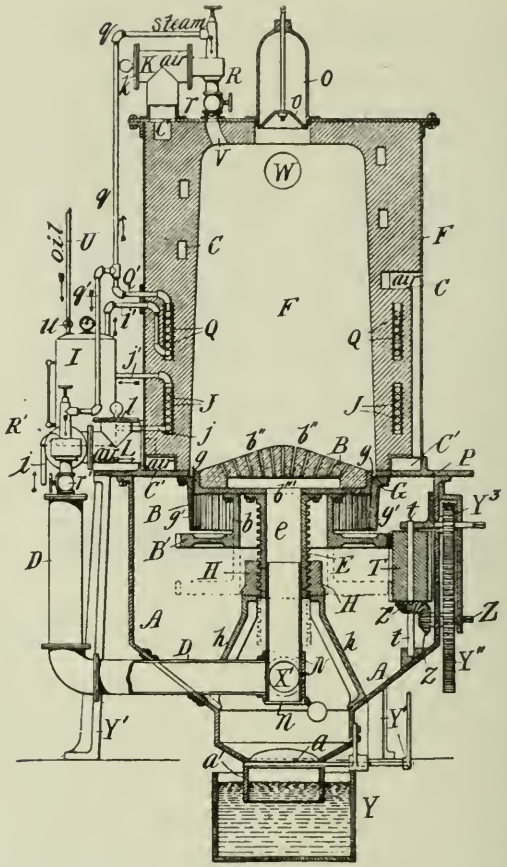

FIG. 2.—Sectional view of the Kitson Gas Generator.

Explanatory.—*A*, ash pit. *B*, fire-brick hearth or grate. *C*, air passageways for heating air supplied to injectors. *D*, injector pipes leading to centre of grate. *E* and *H*, screw and hub for giving grate the rotary and up-and-down motion. *F*, furnace. *G*, vertical grate bars. *I*, steam boiler. *J*, hot-water coils connecting with boiler. *Q*, steam superheating coils, communicating with boiler. *N*, dust valve. *R*, injectors. *O*, hopper to supply coal to furnace. *T*, Y^3, *Z*, mechanism for rotating the grate. *X'*, *W*, gas take-off pipes. *Y*, water seal. *a*, butterfly valve for dumping ashes.

number of incandescent lamps, and occasionally for a small electric motor. The producer is represented in the engrav-

ings (*Figs. 2* and *3*). It occupies about ten square feet of floor space, and stands eight feet from the floor to the top of the feed hopper. This will furnish 1,500 cubic feet of gas per hour. The machine consists of a cylindrical shell of boiler

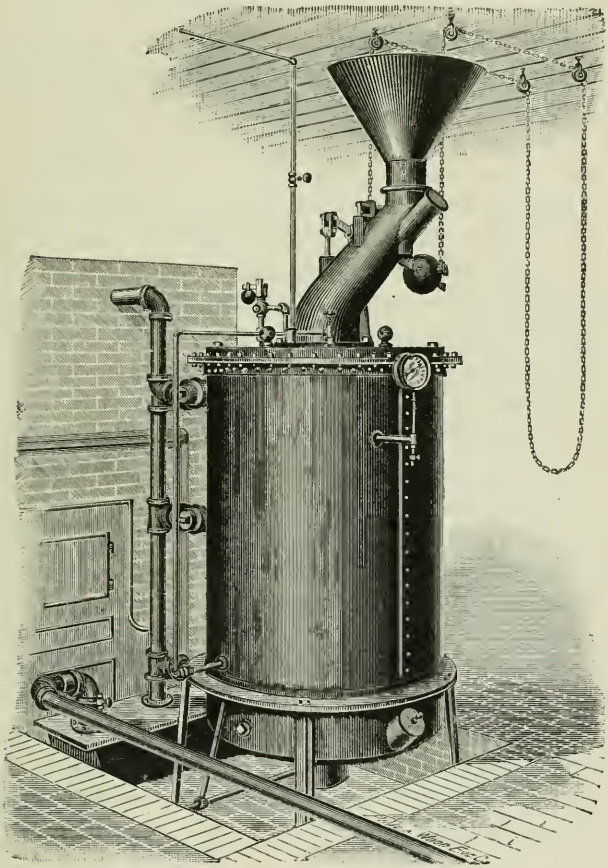

FIG. 3.—The Kitson Gas Generator, exterior view.

iron lined with fire-brick. The internal diameter of the brickwork is 21 inches, and the height from the grate to the top of the furnace is 3 feet 6 inches. The grate is connected on one side with a steam and air injector; on the other, with the gas supply pipe (which runs to the place of consumption),

and is surrounded by a cast-iron box securely attached to the cylindrical shell, forming the ash pit. The whole machine is supported on four cast-iron legs.

The ash box terminates in a mouth-piece, which is opened and closed with a valve operated by a lever from the outside, and serves to dump the ashes, whenever desirable, without interfering with the process of making the gas. The top of the furnace is closed by an iron plate, and upon this the hopper for feeding the furnace is securely fastened. An opening is provided in the plate for a pipe leading to the chimney. Another connection leads also to a gas supply pipe, each of these pipes being opened and closed by valves. A small reservoir forming the boiler is placed on one side and communicating therewith are two coils contained in the brickwork. The lower coil heats the water and furnishes steam, the upper coil superheats it. Water is pumped into the boiler from time to time. An injector is also provided at the top of the furnace. Air channels are arranged spirally in the brickwork, through which air is drawn by the injectors. The air thus becomes heated before mixing with the steam, which must be thoroughly dry. The walls of the furnace, it will be seen, are inclined inwardly towards the top, and outwardly towards the bottom, thus throwing the entire weight and body of the fuel on the grate. The grate is provided with mechanism for giving it a rotary and up-and-down motion, the effect of which is to break up any clinker that may have adhered to the sides of the furnace to keep the coal in a compact mass, avoiding holes in the fuel and to throw the dust and ash into the ash-pit. The caking with soft coal is effectively broken up, and the steam finds an easy passage through it.

The entire gas plant I have described is simple, cheap in construction, and economical in its working. It can be made small enough to produce 500 cubic feet per hour, which means a consumption of only six or seven pounds of coal. It is easily set up, taken down and removed. There is no danger from fire or explosion, and it requires but ordinary care, as in the case of a common coal furnace.

APPLICATIONS OF FUEL (SEMI-WATER) GAS—POWER.

Let us now consider in what manner we may utilize our gas and ascertain the results obtainable. Commencing with the subject of power: It may astonish the general public, who are accustomed to regard the highly developed steam engine as the perfection of human ingenuity in the transformation of heat into work, to learn that the gas engine, with all its imperfections, is a far more efficient instrument. Although the gas engine is limited in various ways, in capacity and power, and is, mechanically speaking, vastly inferior to the steam engine, its absolute efficiency is at least double that of its rival. The absolute efficiency of the gas engine is twenty per cent. and has in some cases exceeded twenty-two per cent. whilst that of the best steam engine never exceeds half this amount. With illuminating gas a consumption of from twenty-five to thirty cubic feet per hour in any of the standard gas engines will develop one actual horse-power, which is equivalent to a consumption of from 15,000 to 18,000 thermal units.

During the past year I have made a great number of experimental tests of semi-water gas with the Körting gas engines, varying in size from eighteen horse-power down to two horse-power, and found no difficulty with a consumption of eighty-five cubic feet in developing an actual horse-power by brake test. This is equivalent to one and one-fourth pounds of coal per horse-power per hour. For several years a well-known firm in Manchester, England, have supplied their works with power by means of gas producers and gas engines, and claim the cost has not exceeded one and three-fourths pounds of coal per horse-power per hour.

A recent test with an Atkinson engine gave one horse-power with $1\frac{11}{100}$ pounds per hour.

In comparison with the steam engine, these results are startling. Compare, for instance, the efficiency of the best steam plant, comprising furnace, boiler and engine, with gas producer and gas engine. It is hardly fair to make comparisons with very large steam plants, for the simple reason that the largest gas engine does not exceed 100 horse-power.

A fifty horse-power steam plant of the most approved pattern will consume 45,000 thermal units in the production of each horse-power per hour, an efficiency of less than seven per cent. In the largest plants the efficiency will not exceed ten per cent. Now, take the gas plant: We get an efficiency in the gas producer of eighty to eighty-five per cent., and in the gas engine from eighteen to twenty-two per cent., an absolute efficiency of from fourteen and one-half up to nearly nineteen per cent. for the entire plant. Here is a method for the supply of power for which there is an unlimited field, and, notwithstanding the years that have elapsed since attention was first called to the subject, it is entirely unknown to the public generally. Instead of large reservoirs for the supply of steam, we may generate gas as required, converting its potential energy into useful work more economically and more efficiently than has ever been dreamed of by steam engineers. The gas producer and gas engine must eventually supplant steam for all small uses, at least.

My experiments showed me:

(1) That it is decidedly advantageous to clear the cylinder entirely of the exploded products before taking in a fresh charge.

(2) That a higher compression than that ordinarily used with illuminating gas is beneficial.

(3) That sufficient time should be allowed to enable the gas and air to intermingle in the exact proportions for combustion, before ignition.

The presence of a small proportion of the exploded products in the new charge affects this quality of gas much more disastrously than where a richer gas is used. There being already fifty per cent. of non-explosive gas in the charge itself, the addition of a small percentage of so injurious a diluent as carbonic acid gas, injures the explosive force of the charge materially.

The best effects from the use of this gas may, therefore, be expected from engines having a variable piston stroke, such as the Atkinson.

The disadvantages attending the slow combustion of

carbonic oxide gas (especially when this gas is accompanied by much nitrogen), is, to a great extent, remedied by high compression. High compression also increases the capacity of a given-sized engine, a decided advantage where semi-water gas is used.

The outlook for the gas producer and gas engine is very encouraging, and bids fair to outrival the steam boiler and engine. Not only is it more economical in the conversion of potential heat units into work, but there is less labor involved and less danger.

The results I have mentioned may at first sight seem startling, especially to those accustomed to the use of small steam plants, where the consumption of coal varies all the way from four to ten pounds of coal per horse-power. So accustomed have we become in our crude utilization of natural forces, to throw away more than we use, that we are apt to lose sight of the proportion and magnitude of such waste.

Every factory and household chimney, every locomotive stack, every ash pit and dust bin testify to the frightful extravagance in our modern and much vaunted methods of utilizing fuel. When we reflect that in every pound of coal lies hidden a force which, if wholly utilized, would furnish four or five horse-power, whilst at present we employ at least ten pounds, and often forty, to accomplish the same results; that in our highly efficient gas motor we consume five volumes to obtain the energy contained in one. some idea of the present wasteful methods of producing power may be realized.

The prediction, therefore, that the gas engine and gas producer will shortly furnish power with one pound of coal per actual horse-power per hour, is only incredible to those who regard present achievements as the summit of human attainment.

LIGHT.

This question of cheap power brings us directly to another—the production of light. The great obstacle the electric light encounters when competing with gas is the cost of power. Here, it seems to me, is a solution of the problem.

Taking an incandescent electric plant, capable of furnishing ten lamps of sixteen candle-power to the actual horse-power, the cost of coal would be less than one-quarter cent per hour. This would permit the use of storage batteries and allow a margin for loss in discharging. The gas is also available in connection with the incandescent gas lamps, such as the Welsbach and Lungren. I have used the former with success. The Kitson water gas lamp, in which the gas is carburetted by the vapor of naphthaline, produces a very beautiful light with semi-water gas.

HEAT.

For heating purposes its uses are almost endless. With properly constructed burners, gas cooking and heating stoves are available for domestic purposes, whilst for industrial work its different uses are legion—brick burning, lime burning, soldering pots, singeing yarns, roasting and smelting furnaces, cupolas, etc., and, in fact, wherever artificial heat is required, this gas may be made available in one special way or another.

DISTRIBUTION.

Chief among the items that make the price of gas high to consumers is the cost of distribution, and in large cities it is certainly attended with the greatest conceivable annoyance and expense. The tearing up of roadways, the laying, relaying and repairing of pipes, the loss from leakage, the suits for damages, the conflicts with City Councils, with surveyors, with street-car companies, and with property owners, serve to make the lot of a gas company at times anything but a happy one. These expenditures have to be met, and serve to make the price of gas to the consumer wholly out of proportion to its cost of manufacture.

The plan I wish to suggest for supplying fuel gas, in its three departments, as light, heat, and power, is, to bring the place of manufacture and point of consumption as near together as possible, and avoid long distance of delivery. I would let every block of houses contain its own gas works and electric light station. A basement in the centre of a

block would be provided and equipped with several gas generators, gas engines, dynamos and storage batteries. This plant I would erect in a substantial manner, and, where necessary, dig below the basement for several feet. I would put in good foundations and sink the generators considerably below the floor level for convenience in supplying the hoppers with coal. One set of generators I would keep constantly in operation, running gas engines which would operate the dynamos, continually charging the storage batteries to supply the necessary lights. This part of the plant I would operate twenty-four hours a day so as to reduce the size and cost of the plant requisite to do a given amount of work. Another set of generators would furnish gas for heating and cooking. Boilers would be used for supplying steam heat or hot water in the ordinary manner. Pipes would be run from the main tank to each house in the block, and wires connected from the storage batteries in the usual way. It would be necessary to have a small holder under each house, which I would also sink below the floor level in the basement. This holder would regulate any great variation in the supply of gas. Each block would thus be provided with its own plant, and be entirely independent of central stations and city gas companies. Duplicate sets of machines would have to be kept ready in the event of one or more of the others giving out. The advantages to be reaped by this system would be, first, that owing to the short distance which the gas and electric current would have to travel, the cost of supply, as well as the amount of capital invested, would be reduced to a minimum; second, this system avoids at once the overhead wire nuisance and the annoyance of tearing up the streets to alter and change the gas mains; third, consumers would be entirely independent of City Councils and city franchises; they would have simply to consult themselves and their own interests, and deal with their own property; and, lastly, an accident to one gas plant would not interfere with the lighting of a whole district, as is the case under the present system.

By this method of distribution you will see that the objec

tion urged against the carrying of a quantity of inert gas, necessitating very large mains, disappears.

I am about introducing this system into a block of buildings in New York City as an experiment, and shall be happy to give you, at a future time, the results of that experiment.

PROCEEDINGS
OF THE
CHEMICAL SECTION
OF THE
FRANKLIN INSTITUTE.

[*Stated meeting held Tuesday, November 17, 1891.*]

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, November 17, 1891.

Dr. W. H. WAHL, President, in the chair.

Nominations of officers to serve during the coming year were made, as required by the by-laws.

In the cases of President, Secretary, Treasurer and Conservator, the present incumbents, namely, Dr. Wm. H. Wahl, President and Conservator; Dr. Wm. C. Day, Secretary; Dr. H. W. Jayne, Treasurer, were re-nominated.

Dr. E. F. Smith and Dr. Wm. H. Greene were nominated as Vice-Presidents.

The following nominations for membership in the Section were made, viz: Mr. Geo. W. Whyte, of the Camden Iron Works, Camden, N. J.; Mr. Alfred N. Seal, 417 Locust Street, Philadelphia; Dr. Herbert M. Kaufmann, 1325 Franklin Street, Philadelphia, and Mr. S. W. Young, of Swarthmore College, Pa. These nominations were referred to the Committee on Admissions, by whom they were favorably considered, and the persons named were declared elected.

Letters of resignation from Mr. Everett W. Frazer, at present of New York City, and Mr. A. A. Moore, of the Franklin Sugar Refinery, Philadelphia, were read, and the resignations were accepted.

A letter from Mr. M. Carey Lea was read, transmitting to the Section the gift of a collection of his published papers on allotropic forms of silver and a set of specimens of the various modifications of the element which he had prepared. They were examined with much interest by the members present, and, on motion, the Secretary was directed to write Mr. Lea a letter of thanks, conveying the Section's appreciation of the gift.

A number of bills for subscription to journals and also for postage and expenses incurred in sending out notices, were referred to the Finance Committee; they were indorsed by the committee, and payment was authorized.

Mr. Lee K. Frankel read a paper "The Oxidation of the Metallic

Arsenides by the Electric Current." The paper was listened to with interest, and was referred for publication in the *Journal.*

This was followed by one from Mr. Otto Lüthy, on "Carbonic Acid Determination." Specimens of potash pumice and other materials discussed in the paper were submitted for inspection. The paper was referred for publication, and the author stated that at the next meeting he would present the results of a further prosecution of the investigation.

Adjourned. WM. C. DAY, *Secretary.*

I. THE IODATION OF *p*-BROMOBENZOIC ACID. II. SALTS OF *p*-BROMO-*m*-NITROBENZOIC ACID.

BY OLIVER HOUGH.

[*Read at the stated meeting, held October 20, 1891.*]

It is stated by Weselsky (*Annalen*, **174**, 99) that the method of iodation recommended by him is not applicable in the case of bromobenzene, or benzoic acid. Believing that possibly a different result might be obtained with bromobenzoic acid, in which two hydrogen atoms are replaced by different substituents, the following experiments were made:

(1) Ten grams of *p*-bromobenzoic acid, dissolved in alcohol, were heated with the calculated amounts of iodine and mercuric oxide. The product was heated with an aqueous solution of sodium carbonate, and filtered while hot. Hydrochloric acid was added to the cold solution, and the liberated organic acid converted into its barium salt. Analysis showed it to be the barium salt of *p*-bromobenzoic acid. The iodation had not been effected.

(2) It was suggested that possibly the iodation had really occurred, but that the sodium carbonate had again removed the iodine. To ascertain whether such was really the case, the acid after treatment was digested immediately with barium carbonate. The resulting salt proved to be *p*-bromobenzoate of barium.

(3) A third experiment was equally fruitless. Finally, the *p*-bromo-acid, in alcoholic solution, was heated together with iodine and mercuric oxide, in a sealed tube. The temperature of the oven was 150° C. Iodine was not introduced into the acid even in this way.

II. SALTS OF *p*–BROMO—*m*–NITROBENZOIC ACID (m. p. 199° C).

The known salts of this acid are those of barium, magnesium and silver. The following are new:

The *potassium salt* forms yellow-colored prismatic needles, varying in length from one-half to one inch. One hundred parts of water at 26° C. dissolve 33·44 parts of the salt. The salt is anhydrous.

The *sodium salt* crystallizes in needles. It contains one molecule of water of crystallization; 100 parts of water at 26° C. dissolve 16·01 parts of the salt.

The *ammonium salt* separates from aqueous solutions in anhydrous needles; 100 parts of water at 26° dissolve 12·22 parts of the salt.

The *strontium salt* consists of minute white needles. It contains three and one-half molecules of water of crystallization. Found 14·88 per cent. Sr instead of 15·10 per cent.; 100 parts of water at 26° dissolve 0·88 parts of the salt.

The *calcium salt* consists of white needles. The air-dried salt lost, when carefully heated in an air-bath at 160°, 30·25 per cent. of water, corresponding to thirteen molecules. Found 7·45 per cent. Ca instead of 7·54 per cent.; 100 parts of water at 26° dissolve 1·09 parts of the salt.

The *zinc salt* crystallizes in white needles; 100 parts of water at 24° C. dissolve 0·70 parts of the salt. The addition of zinc chloride to a solution of potassium nitrobromobenzoate, produced a white precipitate which crystallized from hot water in round, yellow-colored masses. Under the microscope these appeared to consist of bundles of little plates. An analysis of the salt showed it to be the basic zinc salt. It contains three molecules of water. Found zinc = 20·24 per cent. instead of 19·87 per cent.

The *mercury salt* is anhydrous and white in color; 100 parts of water at 26° dissolve 0·96 parts of the salt. Found Hg = 44·04 per cent. instead of 44·90 per cent.

The *nickel salt* crystallizes in light green colored crusts; 100 parts of water at 26° dissolve 1·47 parts of the salt. It contains two and one-half molecules of water.

The *cobalt salt* consists of pink needles. It contains three molecules of water; 100 parts of water at 26° C. dis-

solve 1·05 parts of the salt. Found 11·53 per cent. Co instead of 10·74 required.

I carried out the above work in the laboratory of Dr. Edgar F. Smith, University of Pennsylvania.

THE OXIDATION OF METALLIC ARSENIDES BY THE ELECTRIC CURRENT.

BY LEE K. FRANKEL.

[*A paper read at the meeting, November 17, 1891.*]

The decomposition of minerals and their subsequent oxidation by means of the electric current is a product of very recent origin. By reference to the literature of the subject, it will be found that the first attempt in this direction was made by Dr. Smith, in a paper published in the *Proceedings of the Chemical Section of the Franklin Institute*, vol. i, p. 52, in which the author has successfully completed the decomposition of chalcopyrite and gives the results of some preliminary investigation on chromite.

In a later and more exhaustive paper in the same journal, Dr. Smith has published his researches on the decomposition of other sulphides, and has proven conclusively that oxidation by the electric current gives results as quantitatively correct as those obtained by any wet or fusion method. In a still later paper by the same author (*American Chemical Journal*, vol. 13, No. 6), experiments on various kinds of chromite, indicate that the decomposition of this mineral is complete, if the conditions prescribed are closely followed. At present this completes the literature of the subject, and judging from the success so far obtained, it was deemed advisable to attempt the oxidation of the metallic arsenides, with the hope that the result would be similarly fruitful. These results and the methods used for obtaining them will be found appended below.

The apparatus used for this purpose was the same as that described by Dr. Smith in the *Proceedings of the Chemical Section of the Franklin Institute*, vol. ii, p. 53, and the method of using it was also substantially the same. The

current generated from four storage cells of the Julien type, was passed through the resistance frame, then through a Kohlrausch ampèremeter, and lastly up through the nickel crucible, the latter being in all cases the positive pole. As for the oxidations, the time required, the strength of current, etc., differed in each mineral respectively. For this reason no general plan can be prescribed, but the details of the work will be found for each mineral, under its respective heading.

Gersdorfite (*Ni.Fe.*),*As.S.*—The sample used for the decomposition came from Shladming. The method of procedure was as follows: In a nickel crucible 1¼ inches high and 1⅜ inches wide, 25–30 grams of solid caustic potash were placed. The contents of the crucible were heated until fusion took place, and the gersdorfite then carefully added. A current registering one ampère was passed through the mass for twenty minutes, the crucible being the anode. Towards the end of the operation, the current was reversed for three minutes to remove any particles of mineral that might have been enclosed in the metal dedosited on the cathode. After breaking the current, the crucible was allowed to cool, then thoroughly disintegrated with water, and the resultant insoluble material (nickel and iron oxides) filtered off. The clear filtrate was acidulated with concentrated hydrochloric acid, and then made strongly alkaline with ammonium hydrate. The precipitate (silica and alumina from the caustic potash), which formed on the addition of the latter reagent, was filtered off, and magnesia solution added. The precipitate of magnesium ammonium arseniate, which formed after standing twelve hours, was filtered off, dissolved in dilute hydrochloric acid, re-precipitated with ammonium hydrate, filtered, dried, weighed and ignited in a platinum crucible, in the manner prescribed for this determination. The results obtained were as follows: (1) ·2777 gram of ore gave ·2853 gram of magnesium pyroarseniate = 49·73 per cent. arsenic; (2) ·1137 gram of ore gave ·1173 gram of magnesium pyroarseniate = 49·94 per cent. arsenic; (3) ·2548 gram of the ore was dissolved in nitric acid, evaporated to dryness, the residue taken up in hydrochloric acid, and the arsenic acid reduced with sulphurous acid. Hydrogen

sulphide was then added, the resulting arsenious sulphide filtered off, dissolved in nitric acid, the solution made alkaline with ammonium hydrate, magnesia mixture added, and the arsenic determined as above; ·2617 gram of magnesium pyroarseniate was found = 49·72 per cent. arsenic.

The insoluble residue remaining after the fusion was dissolved in water, was treated with nitric acid and evaporated to dryness. Hydrochloric acid was then added, and hydrogen sulphide passed through the solution for several hours, without the formation of any precipitate of sulphide of arsenic, showing that the mineral must have been completely decomposed.

Niccolite (*Ni.As.*)—With this mineral, the attempt was made to see what effect currents of greater intensity would have on the decomposition. It was hoped that with a current of greater strength the decomposition could be effected in less time, but as will be seen, the results, as far as a diminution of the time limit is concerned, are practically negative.

Two samples of the finely ground niccolite were subjected to a current which varied from $1\frac{1}{2}$ to $1\frac{3}{4}$ ampères, for twenty minutes, and without any reversal of the current, 25–30 grams of caustic potash being used. In both cases did the residues which remained after disintegrating the fused mass with water, show the presence of arsenic, on treating the residues with nitric acid, evaporating to dryness, and the subsequent addition of hydrochloric acid and hydrogen sulphide. The presence of arsenic in the residues is probably due to the fact that the greater strength of current used in the decomposition, deposits larger quantities of metallic nickel on the cathode, enclosing at the same time appreciable quantities of undecomposed mineral.

A much weaker current was now tried. Two samples of the mineral were subjected to a current of half an ampère for twenty minutes, 25–30 grams of caustic potash being used. The result was the same as in the previous case, arsenic being found in both of the residues.

The time limit was now extended with more satisfactory results, the manner of decomposition being as follows: A

current of one ampère was allowed to pass through the fused mass for twenty-five minutes, the current passing up through the crucible. At the end of this time, the current was reversed for five minutes, to remove the metal and any undecomposed mineral that may have attached itself to the platinum wire. The subsequent operations of extracting the alkaline arseniate and weighing it as magnesium pyroarseniate, were similar to those already given under Gersdorfite, with the exception that instead of filtering the precipitation of magnesium ammonium arseniate through filter paper, and igniting it in a platinum crucible, the precipitate was filtered directly through a porcelain Gooch crucible, of the pattern recommended by Prof. Caldwell. Owing to the fine, granular condition of the precipitate, this requires some care, particularly if the filter pump be used. The best results were obtained by first placing a layer of glass wool in the crucible and covering this with a layer of asbestos. After filtering, the crucible with its contents was first dried on a hot plate until all moisture was removed, and then gradually heated over a Bunsen burner for an hour. In this time all the precipitate will be converted into magnesium pyroarseniate. It is hardly necessary to state that the flame from the burner should not be allowed to enter the crucible below, lest a partial reduction of the precipitate ensue. It was also found advisable to allow the crucibles to stand for twelve hours after ignition, since the constant change in temperature made appreciable differences in the weighings. The results were as follows; ·1209 gram of niccolite gave ·1301 gram of magnesium pyroarseniate = 52·09 per cent. arsenic; 0·1540 gram of niccolite gave 0·1672 gram of magnesium pyroarseniate = 52·55 per cent. arsenic.

The residues left after disintegrating the fusions gave no reactions for arsenic. They both had a peculiar crystalline appearance resembling minute plates. They dissolved in nitric acid without any evolution of nitrous fumes, and are probably oxide of nickel.

Another sample of the ore was dissolved in nitric acid, the excess of acid evaporated, ammonium hydrate added along with magnesia solution, and the arsenic determined

in the usual manner as magnesium pyroarseniate, the weighing being made in a platinum crucible, with the following result: 0·2611 gram of niccolite gave 0·2833 gram of magnesium pyroarseniate = 52·52 per cent. arsenic.

Arsenopyrite (*Fe.As.S.*)—The conditions under which arsenopyrite is decomposed are very similar to those of niccolite. The quantity of caustic potash used, the time of decomposition, the reversal of the current, etc., are precisely the same, the only difference between them lying in the fact that in the decomposition of arsenopyrite it was found that the current might vary from one to one and one-half ampères without affecting the decomposition. The method of determining the arsenic, as far as the Gooch crucible, etc., is concerned, was the same as under niccolite. Results as follows:

0·2168 gram of arsenopyrite gave 0·1729 gram of magnesium pyroarseniate = 38·6 per cent. arsenic.

0·1709 gram of arsenopyrite gave 0·1356 gram of magnesium pyroarseniate = 38·41 per cent. arsenic.

The residues from the fusions, treated similarly to those under niccolite, showed no traces of arsenic.

0·2306 gram of the ore were dissolved in concentrated nitric acid, evaporated to dryness, treated with hydrochloric acid and water, and any insoluble matter remaining, filtered off. The solution was then reduced with sulphurous acid, the excess removed by boiling, and the arsenic precipitated by hydrogen sulphide. The solution was then allowed to stand until the odor of hydrogen sulphide was barely perceptible, and then filtered on a porcelain Gooch crucible, washed with cold water, carbon disulphide and alcohol, dried at 100° C. and weighed. The result was 47·73 per cent. As. As the high result could be due to but one cause, viz: the presence of sulphur in the precipitate, repeated treatments with carbon disulphide and alcohol were given the latter, but without avail. The precipitate was eventually dissolved in nitric acid, and the arsenic thrown out with magnesia solution. Found: 0·1856 gram of magnesium pyroarseniate = 38·96 per cent. arsenic.

It will be seen from this, that the determination of arsenic

directly as arsenious sulphide by weighing on a porcelain Gooch crucible is not practicable. The method was tried with various other minerals, and in but one case was the result within limits, due more to accident than to any virtues of the method. The difficulty seems to lie in the fact, that the precipitate settles very compactly in the crucible, and prevents the carbon disulphide from obtaining more than a surface contact with it. In some instances, the crucible was placed in a beaker, covered with carbon disulphide, and allowed to stand for twenty-four hours, without any appreciable difference becoming manifest in the result.

Metallic Arsenic (*As.*)—In the oxidation of the metallic arsenic, a difficulty was encountered which the previous minerals had been free from. It was noticed that if the conditions previously mentioned were followed, viz: that the caustic potash be brought to a state of fusion, and the powdered mineral added, a volatilization of some of the arsenic invariably occurred. In fact, so rapidly did this take place, that barely did the mineral come in contact with the fused potash, but what the garlicky odor of arsenic was perceptible. To obviate this loss, the following method was found to be the best, and, in fact, the only one that would give accurate results. The caustic potash was introduced into the crucible, carefully heated to drive out all moisture, and eventually brought to complete fusion. The flame was now removed, and the mass allowed to cool until it was almost solid, when the powdered arsenic was carefully spread over the surface of the potash. The platinum wire is now placed in position and the current closed. Should the potash have cooled to such an extent that the current will no longer pass through the mass, or at least only with difficulty, a very small flame carefully played under the crucible will remedy the trouble. The arsenic, if these directions are complied with, becomes gradually oxidized, and no volatilization is perceptible. After the first ten minutes, the crucible may be gently heated, until its contents are again in a condition of fusion, and should be kept in such a state until the end of the oxidation. The current used for the operation registered one ampère in the Kohl-

rausch ampèremeter when the potash was completely fused. At the beginning of the oxidation, the resistance offered by the almost solid caustic potash is so great that the current barely registers, but this is exactly the condition that is desirable for thorough results. The current was allowed to run for thirty minutes, being reversed for the last five minutes. The results are as follows:

0·0974 gram of arsenic gave 0·1813 gram of magnesium pyroarseniate = 90·11 per cent. arsenic.

0·1052 gram of arsenic gave 0·1961 gram of magnesium pyroarseniate = 90·23 per cent. arsenic.

The very slight residues which remained after the fusions were treated with water, showed no signs of arsenic. The filtrates from the precipitations with magnesia solution were acidulated with hydrochloric acid and hydrogen sulphide added, to see if possibly some of the arsenic might be present as arsenious acid. No trace of the latter, however, was found.

Another sample of the powdered metal was dissolved in nitric acid, and the arsenic determined in the manner already indicated for the previously mentioned minerals, as magnesium pyroarseniate. It yielded 90·14 per cent. arsenic.

In the two determinations of arsenic in the metallic arsenic, given above, the magnesium pyroarseniate was weighed on porcelain Gooch crucibles.

Rammelsbergite $(Ni.Co.Fe.)As^2$.—With this mineral more difficulty was encountered than with any other, and the results that are given below were obtained only after *seventeen* attempts at decomposition proved unsuccessful. The method used at first was the one which showed itself to be efficient for the decomposition of metallic arsenic, viz: 25–30 grams of caustic potash and a current of one ampère running for thirty minutes, with five minutes reversal at the end of the oxidation. This proved an utter failure, as the residues from the fusion showed in all cases the presence of arsenic, while the results obtained varied from 53–67 per cent. of arsenic. A former experience having shown that the non-oxidation might probably be due to the enclo-

sure of particles of mineral on the platinum wire, a more frequent reversal of the current was tried. Using the same amount of caustic potash, and increasing the current strength from one to one and one-half ampères, the current was reversed after the first ten minutes, and allowed to run in the opposite direction for three minutes. It was then passed up through the crucible again for five minutes, then again down through the platinum wire for three minutes, the process being continued for thirty minutes. The results were altogether unsatisfactory, large quantities of arsenic being found in the residues.

The amount of caustic potash was now increased from 25–30 grams to 40 grams, the nickel crucible used being 1⅞ inches high and 2 inches wide. In six decompositions made under these conditions, the current in the first two had a strength of one ampère, in the second two, of an ampère and one-half, and in the last two it was increased to one and three-quarters ampères, the current being reversed in a manner similar to the one previously tried. The results in all cases were of a negative order, as arsenic was found in all the residues. An increase of the time limit was now tried with satisfactory results. Using forty grams of caustic potash, the current was allowed to act for forty-five minutes. After various attempts to ascertain the best current strength for the purpose, it was found that a current that registers an ampère was the most satisfactory, and it should not be allowed to rise above this point, otherwise the decompositions are apt to be incomplete. In the oxidations given below, the current was reversed at the end of every ten minutes, for three minutes. Another phase of the operation that seems to be essential, is to have the mineral in as fine a condition as possible. Using the conditions just given, the residues from the fusions showed no arsenic, though they were most carefully examined by the wet method and also before the blow-pipe. The arsenic was precipitated as magnesium ammonium arseniate, and weighed as magnesium pyroarseniate in a platinum crucible, the filter being ignited separately after moistening with ammonium nitrate.

The results found were as follows: 0·1829 gram of rammelsbergite gave 0·2598 gram of magnesium pyroarseniate = 68·76 per cent. arsenic; 0·2168 gram of rammelsbergite gave 0·3118 gram of magnesium pyroarseniate = 69·62 per cent. arsenic.

Another sample of the mineral dissolved in nitric acid and determined as magnesium pyroarseniate gave 70·34 per cent. arsenic.

Chloanthite (*Ni.Co.Fe.*) As^2.—The mineral used for decomposition was a portion of the sample from Franklin, N. J., which was reported along with other minerals, by Dr. Koenig, in the *Proceedings of the Academy of Natural Sciences of Philadelphia*, 1889, 184. The decompositions were made contemporaneously with those of rammelsbergite, and for this reason many of the unsuccessful steps which were made with the latter mineral were also made with the chloanthite. The first oxidations were made with a current of one ampère, using 25–30 grams of caustic potash, and allowing the current to run for thirty minutes. As with the rammelsbergite, so here, too, only diverse results were obtained. Reversing the current every five minutes, after the first ten minutes, brought about a similar condition of affairs. The results were from five to six per cent. low. The addition of copper oxide, as recommended by Dr. Smith in the oxidation of pyrite (*Journal of the Franklin Institute*, proceedings of the Chemical Section, vol. 2, p. 62) was now tried. The quantity of caustic potash used being increased at the same time, with one sample of the chloanthite, an equal amount of copper oxide was mixed, and with another sample double the quantity of copper oxide. The other conditions were a current of one and one-half ampères, a time limit of thirty minutes, with reversals of the current after the first fifteen minutes, and forty grams of caustic potash. This combination of conditions gave no better results than the previous one. Satisfactory results were eventually obtained under the following conditions, the copper oxide being dispensed with entirely: The current was not allowed to register above one ampère, and the best results will be obtained if it is kept slightly below this

mark. Thirty minutes was found to answer for complete decomposition, but for the sake of certainty, it is advisable to allow the current to run for forty-five minutes, reversing it during the last five minutes. The amount of caustic potash used was forty grams. The results obtained were as follows: 0·2332 gram of chloanthite was decomposed as above. The fusion was treated with hot water and filtered. The filtrate was acidulated with hydrochloric acid, and warmed to expel the carbon dioxide present. On cooling, the arsenic was reduced with sulphurous acid, and after the expulsion of the excess of sulphurous acid, was precipitated with hydrogen sulphide in the cold. The precipitate of arsenious sulphide was filtered in a Gooch crucible, after the solution had stood until it barely had the odor of hydrogen sulphide, and washed with cold water. The crucible and its contents were then placed in a beaker, carbon disulphide added and allowed to stand twenty-four hours. The crucible was then removed from the beaker, its contents washed with alcohol, then with cold water, and finally dried for six hours at 105° C.; 0·2710 gram of arsenious sulphide was found = 70·84 per cent. arsenic; 0·2899 gram of chloanthite treated in the same manner as the preceding gave 0·3325 gram of arsenious sulphide = 69·93 per cent. arsenic.

In the sample of the mineral analyzed by Dr. Koenig and reported by him, he found 70·66 per cent. arsenic.

As will be seen from the above, accurate results were obtained by weighing the arsenic as arsenious sulphide. They are, however, but two out of a large number of determinations that were made in porcelain Gooch crucibles, and the only two which gave results sufficiently close to be utilized. The amount of sulphur precipitated with the arsenious sulphide must have been very small, otherwise the results, owing to the inefficacy of the carbon disulphide, would assuredly have been high. For this reason, the author cannot recommend the method for general use.

The residues from the fusions were carefully examined for arsenic but none was found to be present.

Smaltite (*Co.Ni.Fe.*) As^2.—From the experience gained

with rammelsbergite and chloanthite, it was found very easy to oxidize the smaltite. The mineral used for the purpose was mixed with gangue, and therefore was first broken up, and the smaltite picked out as carefully as possible by hand. The resultant material, as shown by the analyses, still contained impurities. The conditions for oxidation are as follows: A current of one ampère with the restrictions imposed under chloanthite, a time limit of forty-five minutes, and forty grams of caustic potash. Using those conditions, the oxidation is complete, the residues showing not the least trace of arsenic. The results obtained were as follows:

0·2233 gram of smaltite gave 0·2813 gram of magnesium pyroarseniate = 60·98 per cent. arsenic.

0·1790 gram of smaltite yielded 0·2199 gram of magnesium pyroarseniate = 59·47 per cent. arsenic.

The method of procedure resembled one already given. The fusion was acidified with hydrochloric acid, then made alkaline with ammonium hydrate, and the arsenic precipitated with magnesia solution, being finally weighed in a platinum crucible. In the latter of the two determinations, the garlic odor of arsenic was noticeable on igniting the filter paper, although it had previously been thoroughly saturated with a concentrated ammonium nitrate solution. This accounts for the slightly low result obtained, but it was not thought necessary to repeat the operation, since the residue showed that the oxidation was complete.

0·3136 gram of the ore, dissolved in nitric acid, and the arsenic determined as magnesium pyroarseniate in a platinum crucible, gave 0·3929 gram of magnesium pyroarseniate = 60·65 per cent. arsenic. The difference in percentage from the theoretical amount is due to the impurities in the mineral.

A study of the composition of rammelsbergite, chloanthite and smaltite will show several points of interest. It will be seen from their formulæ that they each contain two atoms of arsenic to the molecule, while niccolite, cobaltite, arsenopyrite, etc., either have one atom of arsenic to the molecule or have one atom of arsenic replaced by sulphur.

Returning to the study of the conditions necessary for oxidation, it will be remembered that the amounts of caustic potash necessary, and the extents of time, were larger for the first three minerals than for any of the others, while the oxidations seem to proceed with greater difficulty. A cause for this that might be advanced, is that the oxides of the metals are united with greater tenacity to two arsenic atoms than they are to one, and require a greater expenditure of force for their separation. A somewhat similar occurrence was noticed by Dr. Smith in the oxidation of the metallic sulphides. Pyrrhotite, whose formula is in all probability either $Fe_{11}S_{12}$ or FeS, is decomposed with great readiness, while pyrite, which contains two atoms of sulphur to the molecule, succumbed only after repeated and many fruitless trials. What might be considered a curious feature in the oxidation of these arsenides is the fact that those containing two atoms of arsenic to the molecule are decomposed more readily by weak currents than they are by strong ones, while with the arsenides containing but one atom to the molecule, either strong or weak currents are equally efficacious. The only explanation that there is to offer for this seeming anomaly, is the one already given, viz: the enclosure of particles of metal on the platinum wire. In those arsenides containing but one atom of arsenic to the molecule, the decomposition is in all probability so rapid, that any enclosure of the mineral on the wire is practically impossible. In minerals like rammelsbergite and chloanthite we may assume that the decomposition proceeds by much slower stages, so that if the current is sufficiently strong to deposit metal on the cathode, there is constantly present sufficient undecomposed mineral to be enclosed in the deposited metal.

Cobaltite (*Co.Fe.*)*As.S.*—This mineral was decomposed with great ease, a result to be expected if we trace the similarity in composition between it and such minerals as gersdorfite, niccolite, etc. The conditions for oxidation are very similar to those of gersdorfite, with the difference, that while, in the latter, the current was allowed to run only for twenty minutes, in the decomposition of cobaltite it ran for

thirty minutes, with a five minutes reversal at the end. Otherwise the conditions for oxidation and for the subsequent decomposition of the fusion and the estimation of the arsenic, are the same as for gersdorfite. The magnesium pyroarseniate was weighed in platinum Gooch crucibles, the method being very accurate, owing to the fact that there is no possibility for any volatilization of the arsenic, and more rapid than weighing in a porcelain Gooch crucible, since the platinum crucible attains a constant temperature in a very short period of time. The results obtained were as follows:

0·1032 gram of cobaltite yielded 0·1006 gram of magnesium pyroarseniate = 47·2 per cent. arsenic.

0·1326 gram of cobaltite yielded 0·1313 gram of magnesium pyroarseniate = 47·93 per cent. arsenic.

0·2250 gram of the same ore was dissolved in nitric acid, the acid evaporated, the solution made alkaline with ammonium hydrate, and the arsenic precipitated with magnesia solution. The resultant magnesium ammonium arseniate was ignited in a porcelain Gooch crucible and gave 0·2229 gram of magnesium pyroarseniate = 47·96 per cent. arsenic.

Orpiment (As_2S_3).—The preliminary investigations made with this mineral showed that it came under the same category as the metallic arsenic. When the finely powdered mineral was introduced into the molten caustic potash, a volatilization of the arsenic, recognizable by its odor, occurred. The precautions given under metallic arsenic, regarding the cooling of the caustic potash and the regulation of the current, were then introduced, with successful results. Some difficulty may at first be experienced in obtaining correct control of the operation, but a few oxidations will give the operator sufficient experience to bring the decomposition to a successful completion. The conditions best adapted for the work are a current of one ampère, 25–30 grams of caustic potash, the current being allowed to run for thirty minutes. Using these conditions, no arsenic was found in the slight residues which remained after decomposing the fusion, nor was any odor of arsenic perceptible during the entire course of the operation.

0·1443 gram of orpiment, decomposed according to the directions, gave 0·1761 gram of magnesium pyroarseniate = 59·08 per cent. arsenic.

0·1044 gram of orpiment yielded 0·12805 gram magnesium pyroarseniate = 59·38 per cent. arsenic.

0·2233 gram of the same ore, dissolved in nitric acid, and weighed as magnesium pyroarseniate in a platinum crucible, yielded 0·2755 gram of magnesium pyroarseniate = 59·72 per cent. arsenic.

Proustite (Ag_3AsS_3).—But a very small quantity of the mineral was available for analysis, and even that was intimately mixed with argentite. No attempt was therefore made to extract the former mineral by hand-picking, but the entire mixture was placed in an agate mortar and ground, the grindings then being passed through a sieve. This removed all the proustite with some of the argentite, the greater portion of the latter remaining behind as flattened plates. Sufficient argentite, however, remained with the proustite, to reduce in a considerable measure the percentage of the arsenic, and the deviation of the results from the theoretical percentage is attributable to this cause. Sufficient material was not at hand to make a check analysis, by dissolving the mineral in nitric acid and determining in the usual way, but as the residues were most carefully examined for arsenic, and as none was found to be present, the natural conclusion arrived at was, that the decomposition was complete. No loss of arsenic was noticeable during the entire operation, and the closeness of the results indicates that the decomposition of this mineral by the electric current can be accomplished as successfully as any one of those previously described. The conditions for oxidation were as follows: A current of one ampère running for thirty minutes, the current being reversed during the last five minutes. The amount of caustic potash used was 25–30 grams. Below will be found the results obtained:

1·1589 gram of proustite, weighed as magnesium pyroarseniate in a porcelain Gooch crucible, gave 0·0147 gram of magnesium pyroarseniate = 4·48 per cent. arsenic.

0·2255 gram of proustite yielded 0·0249 gram of magnesium pyroarseniate = 5·34 per cent. arsenic.

Besides these minerals already recorded, several others were subjected to oxidation by the current, but owing to lack of material for the continuance of the work, satisfactory conclusions were not reached. The results are, however, of interest, and are, therefore, here appended.

Domeykite in Niccolite, $n(Ni.As.) + m(Cu^3As.)$—The mineral used for oxidation came from Michipicoten Island, and was a small section of a specimen in the mineral collection of the University of Pennsylvania, labelled whitneyite. Two oxidations of the mineral, in which the residues still showed arsenic, gave, to the surprise of the author, 35·3 per cent. and 40·04 per cent. of arsenic, respectively, showing that the mineral could not be whitneyite, since this should contain theoretically 11·64 per cent. of arsenic. A later oxidation gave, using 0·2207 gram of the mineral, 0·2016 gram of magnesium pyroarseniate = 44·22 per cent. arsenic. 25–30 grams of caustic potash were employed, with a current of one to one and one-half ampères, for thirty minutes, reversing the current at the end for five minutes. In this oxidation no trace of arsenic was found in the residue. On reporting the results obtained to Dr. Koenig, he made an analysis of another sample, by dissolving the mineral in nitric acid, and found it to contain 47 per cent. of arsenic. This result is, however, not inharmonious with the last one obtained by the current, since, in a fresh fracture of the mineral, the niccolite and domeykite can be seen lying alongside of each other. Owing to this non-homogeneity, the sample analyzed by Dr. Koenig may have contained more niccolite than the one used for oxidation by the current, and gave proportionately a higher percentage of arsenic. Unfortunately, the scarcity of the mineral necessitated the discontinuance of the work, and the question of complete oxidation is still in doubt. The few per cent. difference in the results obtained by the two methods, however, indicates that the decomposition can be successfully accomplished under the conditions mentioned above.

Enargite ($3Cu^2S.As^2S^5$).—The material used for decompo-

sition contained an admixture of gangue, and as with the domeykite, not sufficient of the substance was obtainable to settle thoroughly the question of oxidation. As the percentage of arsenic found, however, is within the neighborhood of what the mineral ought to contain, and as no arsenic was detectable in the residue from the fusion, the result obtained is here appended, without any definite statement regarding the thoroughness of the method. The amount of caustic potash used in the oxidation was 25–30 grams, the current strength one ampère, with a reversal of the current at the end of the operation for five minutes. The arsenic was determined by weighing as magnesium pyroarseniate on a porcelain Gooch crucible.

0·2840 gram of enargite gave 0·0770 gram of magnesium pyroarseniate = 13·12 per cent. arsenic.

The theoretical percentage of arsenic in the mineral is 19·1 per cent. If we remember, however, that the sample used contained gangue material, and that no arsenic was found in the residue, it is but fair to assume that the result lies within the limits of error, and that the oxidation is complete. No positive statement, however, can be made.

A study of the methods used for the determination of the arsenic in the various oxidations, will be of interest. As has already been stated, the determination of the arsenic as arsenious sulphide, by weighing on a porcelain Gooch crucible, cannot be recommended, owing to the great difficulty experienced in removing the sulphur with which the precipitate of arsenious sulphide is contaminated. The more common method of weighing the arsenic as magnesium pyroarseniate was found to be accurate, if the conditions laid down for this determination are complied with, the method requiring at the same time great care. In the incineration of the filter from the magnesium ammonium arseniate, constant vigilance was required to prevent a volatilization of a portion of the arsenic, even though the filter had been previously saturated with a concentrated ammonium nitrate solution. And in many cases it was necessary to moisten the burnt filter several times with the solution

before it could be completely reduced to ash. Weighing the precipitate on either a platinum or porcelain Gooch crucible removes these sources of error, and is, of all the methods so far mentioned, the most to be recommended. In the precipitations with magnesia solutions, it was noticed that the presence of large quantities of alkaline salts have a tendency to materially retard the precipitation of the magnesium ammonium arseniate, and it became necessary to allow the solution to stand at least forty-eight hours before the precipitation was complete. For this reason, where large quantities of alkaline salts are known to be present, for example, the caustic potash used in the fusion, it may be more advisable to reduce the arsenic with sulphurous acid, precipitate it as arsenious sulphide, filter and wash, and then reconvert it into arsenic acid and determine as magnesium pyroarseniate.

Owing to the time and care required in the above determinations, the method described in *Sutton's Volumetric Analysis*, sixth edition, as recommended by Pearce, of the Colorado Smelting Company, was tried. The substance of the method is as follows: "The arsenic brought into the form of alkaline arseniate is acidified with nitric acid, and boiled to remove carbon dioxide and nitrous fumes. It is then cooled to the ordinary temperature, and almost exactly neutralized as follows: Place a small piece of litmus paper in the liquid; it should show an acid reaction; now gradually add strong ammonia until the litmus turns blue, avoiding a great excess. Again make slightly acid with a drop or two of strong nitric acid, and by means of very dilute ammonia and nitric acid, added drop by drop, bring the solution to such a condition that the litmus paper, after having previously been reddened, will, in the course of half a minute, begin to show signs of alkalinity. The litmus paper may now be removed and washed, and the solution, if tolerably clear, is ready for the addition of silver nitrate. If the neutralization has caused much of a precipitate (alumina, etc.), it is best to filter it off at once, to render the subsequent filtration and washing of the arseniate of silver easier, ——." The latter portion of the process consists in

determining the silver in the silver arseniate, and calculating the percentage of arsenic from the amount of silver found.

A number of determinations were made by the author to ascertain the value of the method, but all of the attempts made resulted in failure. It was found well nigh impossible to tell by the color of the litmus paper whether the solution was acid or alkaline. In several cases, methyl orange was used as an indicator, and while the solution was made slightly alkaline, as recommended by Pearce, the addition of ammonia to the filtrates invariably brought down considerable quantities of silver arseniate, and the results obtained were proverbially low. The silver was not determined by titration, as recommended by Pearce, but by electrolysis. The best result obtained by this method, with the details of the operation, are given below:

A sample of rammelsbergite was decomposed under the conditions mentioned for that mineral. The fusion was decomposed with hot water, the insoluble material filtered off, and the clear filtrate acidified with nitric acid and boiled to remove the carbon dioxide. On cooling, ammonium hydroxide was added, the precipitated alumina, etc., filtered off, and the additions of dilute nitric acid and dilute ammonia made according to Pearce's direction, until the solution became faintly yellow, methyl orange having been used as an indicator. Silver nitrate was now added, the solution stirred, and the precipitate of silver arseniate filtered off. The addition of a drop of ammonium hydrate to the clear filtrate gave a further precipitation, and ammonia was, therefore, added until the precipitation was supposed to be complete. The two precipitates were then united, washed with cold water, dissolved in nitric acid and the excess of acid evaporated. To the solution, ammonium hydrate was added until the solution became alkaline, and then an excess of potassium cyanide, the solution electrolyzed and the resultant silver weighed. 64·21 per cent. of arsenic was found, the same sample giving, by the pyroarseniate method, 70·34 per cent. arsenic.

The author believes that with continued practice, sufficient dexterity might be obtained with the method to obtain

accurate results, but it is hardly one that could be recommended for work outside of a technical laboratory, where absolute accuracy is not so essential a feature, as that the results should be correct, relatively, to each other.

A comparison of the oxidation of the metallic sulphides with that of the metallic arsenides shows several points of difference. In the oxidation of the sulphides, it was observed by Dr. Smith that the process took place in three stages, the sulphur being first oxidized to hydrogen sulphide, then to sulphurous acid and eventually to sulphuric acid. A similar state of affairs was not observed with the arsenides, and the oxidation evidently proceeds directly from metallic arsenide to arsenic acid. Even in samples where the oxidation had not been complete, and where the residues still showed undecomposed material, the filtrates from the fusion showed no trace of arsenious acid after the alkaline arseniate had been removed by precipitation with magnesia solution.

In conclusion, the author would here express his sense of deep obligation to Dr. Edgar F. Smith, for his unremitting kindness during the progress of the above work, and for his constant help in assisting its completion.

Thanks are also due to Dr. George A. Koenig for samples of minerals, and to Mr. D. L. Wallace, of this laboratory, for assistance rendered in the oxidations.

University of Pennsylvania,
Philadelphia, August 3, 1891.

PROCEEDINGS

OF THE

ELECTRICAL SECTION

OF THE

FRANKLIN INSTITUTE.

[*Proceedings of the stated meeting of the Electrical Section, held Tuesday, November 3, 1891.*]

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, November 3, 1891.

Prof. EDWIN J. HOUSTON, President, in the chair.

Present, thirty-five members and visitors.

The minutes of the previous meeting were read and approved.

The Treasurer's bill for printing and clerical work was approved and ordered paid.

Four nominations to membership were referred to the Committee on Admissions, who reported one election since last meeting.

Prof. Edwin J. Houston read a paper, entitled "Is Actinism a Species of Electrolysis?" Referred for publication.

Mr. Willyoung presented a communication on "Resistance Standards: their Manufacture and Adjustment." Referred for publication.

Mr. W. H. Edgerton described "Some Proposed Improvements in the Secondary Battery."

Mr. W. W. Jennings, under the title of "Jove's Autograph," exhibited and described a large and very interesting collection of lantern slides from lightning photographs, most of which were taken by himself; these showed the electrical discharge in many curious shapes, but with an entire absence in all of them of the zigzag form commonly seen in pictorial representations.

The following nominations were made for officers for the year 1892:

President—Prof. Edwin J. Houston.

Vice-President—Messrs. C. W. Pike and Carl Hering.

Secretary—Prof. L. F. Rondinella.

Treasurer and Conservator—Dr. Wm. H. Wahl.

The meeting then adjourned.

L. F. RONDINELLA, *Secretary*

Is ACTINISM a SPECIES of ELECTROLYSIS?

By Prof. Edwin J. Houston.

[*Read at the stated meeting, held November 3, 1891.*]

In the present paper I have arranged and amplified the substance of the informal remarks made at the last meeting of the section, concerning the possible identity of actinism in the growing leaf, when exposed to the sunlight, and electrolytic decomposition.

In the growing leaf, in sunshine, a series of complex decompositions occur, which result finally in the deposition of carbon and the evolution of free oxygen.

Assimilation in plants consists, with few exceptions, in a process of deoxidation. The food materials absorbed by plants are generally highly oxidized substances, which are deoxidized during assimilation. This assimilation takes place mainly in cells containing chlorophyll, and this, almost without exception, occurs only in the presence of sunlight.

Sachs, in his *Text-Book of Botany*, says: "It is only the cells that contain chlorophyll, and these only under the influence of sunlight, that have the power of decomposing the carbon dioxide taken up by them, and, at the same time, setting free an equal volume of oxygen, in order to produce organic compounds out of the elements of carbon dioxide and water; or, in other words, to assimilate."

In nearly every species of plants the leaf is presented with one of its faces towards the sunlight, so that one face is illumined and the other non-illumined: or, at least the illumination of one face exceeds the illumination of the opposite face. This latter is especially the case with leaves that are formed of comparatively transparent substances.

That differences of potential exist in the various parts of a growing plant is a fact that is now generally recognized. Too little, however, has been done in this direction to ascertain the exact character of these differences of potential.

Probably one reason so little is correctly known to-day concerning the differences of potential of growing plants, arises from the fact that such differences of potential can be brought about by so many different causes, that probably the differences of potential arising from one cause or set of causes, mask or neutralize those produced by another cause or set of causes.

I desire in the present paper briefly to call attention to another probable source of difference of electric potential, that may still further mask or render difficult of detection the differences of potential existing naturally in growing plants.

Before doing this, however, I will briefly review some of the more important causes which produce differences of potential in growing plants. The principal of these are as follows, namely:

(1) Various chemical processes that occur in the cell walls of the growing plant.

(2) Molecular movements of liquids throughout the plant, which result in the production of diaphragm currents. These molecular movements may either be those caused during the growth of the plant, or may be caused by the mere bending of the plant, by the wind, or other cause external to the plant.

(3) Differences of potential developed in plants which would result in currents of the general character of the demarcation currents observed in animals; that is, currents due to the chemical action of the various liquid materials exuded at the surfaces of injured or abnormal plant tissue.

(4) Differences of potential due to the evaporation of moisture from the surfaces of the leaves, derived either from the rain or dew, or from the evaporation of liquid substances given off from the body of the plant.

(5) Differences of potential arising from the electrolytic decomposition of carbonic acid, or the various forms which carbonic acid derivatives assume during assimilation.

The causes above enumerated, refer to the differences of potential that have their seat in the structure of the plant

itself. Another source of differences of potential is to be found in the differences of electric potential that generally exist between the atmosphere that surrounds the plant, and the earth or soil in which it grows. These differences of potential being neutralized in the various parts of the plant itself would, of course, result in the production of electrical currents.

I desire to call special attention to the fifth head under which I have classed differences of electric potential in plants, viz: those arising from the electrolytic decomposition of the various oxygenated carbon compounds, derived mainly, if not entirely, from the carbonic acid of the atmosphere.

That the action of sunlight on growing plants should partake of the nature of electrolytic decomposition is, perhaps, to be inferred from the general views now held in accordance with Hertz's theory as to the identity between sunlight and electro-magnetic radiations or waves.

These remarks should be regarded merely as suggestions made in the line of further investigations.

As far as our knowledge of growing plants extends the oxygen which results during the general process of deoxidation, under the influence of sunlight appears to be evolved mainly from the non-illumined or darker face of the leaf, while the carbon, or the less highly oxidized carbon compounds, which are utilized by the plant for the production of its woody fibre and woody tissue, though afterwards deposited in all parts of the leaf, are probably mainly liberated at or near the illumined face.

If these facts be as above-mentioned, the decomposition in the leaf under the action of sunlight, of the carbonic acid, or its derivative compounds probably partakes of the nature of electrolytic decomposition.

In this direction I would suggest the following lines of investigation, namely:

(1) To ascertain experimentally whether there exists on the opposite faces of a growing leaf, when exposed to the full action of sunshine, a difference of electric potential resulting from the polarization which always accompanies

electrolytic decomposition; and if this be so, what is the nature of such polarization.

If such differences of potential actually exist, it would of course follow, that the illumined face of such leaves, under polarization, would be mainly electro-negative, since it is at or near this face that the carbon and less highly oxidized carbon compounds appear, while the dark or less illumined face would be electro-positive, since it is here, for the greater part, that the oxygen is liberated.

(2) Whether electrodes suitably connected to the opposite faces of a growing leaf in the presence of sunshine, will show the presence of an electric current arising from an equalization of the difference of electric potential.

The value of these differences of potential on the opposite faces of growing leaves, might, of course, be ascertained by the proper use of an electrometer.

(3) Whether a suitable leaf-battery could not be devised, by connecting, in alternate succession, the opposite faces of a series of leaves on a plant-stalk.

That is to say, connect the illumined face of one leaf with the non-illumined face of another leaf, and so on in series until any feeble differences of electric potential that there might exist are sufficiently multiplied to sensibly affect the needle of a galvanometer.

(4) A comparison of the effects of sunlight and artificial light, such as the electric light, on such electrolytic decompositions.

(5) Whether any differences exist in the case of the light produced by an alternating-current arc light and that produced by a constant-current arc light.

(6) Supposing the presence of the differences of electric potential due to the electrolytic decomposition, to be established, and the direction of the electric currents so produced, known, to ascertain whether an electric current led through the plant in the same direction as the current produced by actinism, would not tend to increase the assimilation and the subsequent growth of the plant; and, whether, on the contrary, an electric current sent in the opposite direction through the growing leaf would not tend to check such assimilation or growth.

According to some experiments recently made in France, it was shown that electric currents sent through plants under certain circumstances promoted growth. These currents were sent through the soil in which the plants were growing, by electrodes placed in the soil. The nourishing substances in a quantity of manure, placed near one of the electrodes, were clearly carried in the line of the current, or between the electrodes.

(7) To ascertain experimentally whether the converse of the proposition is true: namely, whether an electric current of approximately the same strength as that produced by actinism, when sent through the leaf in the opposite direction, would not result in the production of luminous phenomena in the leaf.

The following facts, well recognized in botany, would seem to show, to some extent at least the presence of a species of polarization in certain plants during active growth in sunshine.

In the case of those plants which bend or become concave on the side the most exposed to light: This curvature is due to the fact that a smaller growth occurs on the illumined than on the dark side. This is well recognized in botany, and such plants are called in general *heliotropic* plants. Since they are for the most part highly transparent, considerable light must therefore pass through their entire structure, and the difference in the illumination between the light and dark faces must be comparatively slight. This shows that such differences in growth may occur under comparatively small differences of illumination.

In the case of plants that turn toward the sun: It is a well-known fact that some plants turn towards the light. It is possible that this motion is in some manner the result of the polarization effected, during growth, by the sunlight.

In a series of experiments concerning the effects of the electric light on plant growth, made at the Experimental Station of Agriculture of the Cornell University, some important facts were discovered concerning electric plant-culture.

These experiments seem to show that electric light pro-

motes plant assimilation, and sometimes hastens plant growth and therefore maturity.

The Cornell experiments made during 1889 and 1890 were with the light of a constant current Brush arc lamp. Those made during 1891 were with the light of a Westinghouse alternating current arc lamp.

It would seem to be a matter of considerable interest in the case of these experiments to ascertain definitely, whether any marked differences exist between the action of the light produced by a steady current and that produced by an alternating current. In the line of investigations here suggested, it would of course seem as if the electric decomposition would be less marked in the case of the light produced by an alternating current than that produced by a steady current. And that therefore in those cases where the electric light of the steady current had proved to be injurious to the growth and assimilation of the plants, that with the alternating current light such injurious effects should be less marked.

CORRESPONDENCE.

THE PATH OF A PROJECTILE.

To the Committee on Publications:

Capt. Ingalls, in the November impression of the JOURNAL, takes the occasion to say that the equations given in my October article are to be found in his treatise on *Ballistics*. I desire to state in reference to the subject that the equations given by me were deduced independently of Capt. Ingall's work, and without knowledge of its existence.

I merely stated that the equations were not *generally* given in treatises on mechanics, which statement virtually implied that they had been given before. Capt. Ingalls, however, was not the first to give these equations, although he seems to imply it. If Capt. Ingalls will refer to Newton's *Principia*, book second, proposition four, and translate its geometrical language into analytical symbols, he will obtain all the equations that he has given on the subject.

Very respectfully,

F. GILMAN.

Lowell, Mass., November 16, 1891.

BOOKS RECEIVED.

[In sending books for notice in the *Journal*, publishers are requested, for the information of the reader, as well as for their own advantage, to give the price. This announcement by title will be followed, in most cases, by a review, which will appear at the earliest opportunity.]

A Practical Guide to the Testing of Insulated Wires and Cables. By Herbert Laws Webb. New York: D. Van Nostrand Company. 1891. 12mo, pp. 8–118.

How to Make Inventions or Inventing as a Science and Art. Edward P. Thompson. New York: D. Van Nostrand Company. 1891. 8vo, pp. 161.

The Practical Catechism. A collection of questions on technical subjects, * * * By Robert Grimshaw. New York: John Wiley & Sons. 1891. 24mo, pp. 296. Price, $1.25.

Experiments and Researches on Trap Siphonage. Presented at the Eighteenth Annual Meeting of the American Public Health Association, 1890. By James E. Denton. Concord: Republican Press Association. 1891. 8vo. Pamphlet.

Modern Practice of the Electric Telegraph. By Franklin Leonard Pope. New York: D. Van Nostrand Company. 1891. 8vo.

The Eleventh Census. An Address delivered before the American Statistical Association. By Robert P. Porter. Boston, October 16, 1891. New York Engraving and Printing Company. 1891. 8vo. Pamphlet.

John Wiley & Sons announce the early publication of *The Engine Runners' Catechism*, telling how to erect, adjust and run the principal steam engines in use in the United States; being a sequel to the author's *Steam Engine Catechism.* (Profusely illustrated.) By Robert Grimshaw, M.E. (18mo. Cloth. Price, $2.00.) Also a ninth edition of *The Steam Engine Catechism*, by the same author. (18mo. Cloth. Two volumes in one. Price, $2.00.) Also, *Roofs and Bridges.* Part 3. By Prof. Mansfield Merriman.

BOOK NOTICES.

A Short Manual of Analytical Chemistry. Qualitative and Quantitative; Inorganic and Organic. By John Muter, M.A., Ph.D., F.R.S.E., F.I.C., F.C.S., etc. Edited by Claude Hamilton, M.D., Ph.G., Prof. of Anal. Chem. in the Min. Med. Col., and Kansas City Col. of Pharmacy, etc.

The treatise attempts to cover a very wide range of practical or laboratory instruction, including qualitative and quantitative mineral analysis, detection

of the alkaloids and more commonly occurring glucosides, ultimate organic analysis, special schemes for drug analysis, urinary analysis, analysis of water, air and important foods, together with gas analysis, and the methods of the polariscope and spectroscope.

It is obvious that some parts of this wide field can only be touched upon in the most superficial way.

The qualitative tests seem to be full and satisfactory, notably those for the acid radicals, the volumetric methods are also quite complete, the quantitative sections, however, are hardly more than an outline, while the sections on gas analysis and the polariscope might as well have been omitted for any practical value they will possess to the student.

The book is, however, a valuable compend of information for the student of analytical chemistry. S. P. S.

Hints to Power Users. By Robert Grimshaw. New York: Cassell Publishing Company, 1891. (pp. 160. $1.00.)

The sub-title perhaps more fully explains the intended use of the work, and better than any other language would: it is "Plain, practical pointers, free from high science, and intended for the man who pays the bills."

The advice given is directly to the point, and the book is a good one to be put in the hands of the engine or boiler man about an establishment, after the man who pays the bills has read it. The range covered is, as the author puts it, "from the ash-pit to the exhaust head," and he might have added "taking in all the rest of the mill." H. W. S.

The Patent Franchise in the United States. By G. H. Knight. Temple Court, New York City. (Author, April, 1891.)

It is rarely that any concise publication handles an important subject so well as this. In twenty-four handsomely printed pages, Mr. Knight has given a clear and exact statement of the history of the recognition of property in inventions by protective legal enactments, and the development of public sentiment toward such protection; moreover, he has done so in a very entertaining way and so far as the opponents to patent protection of invention are amenable to reason, he has disarmed them by an array of indisputable facts.

No one can attentively read Mr. Knight's little book without realizing that every inhabitant of this country has either directly or indirectly been benefited by the legal recognition of the patent franchise, although there are doubtless many who don't know it, and demagogues ready to work upon their ignorance have raised prejudices against the patent system. In one particular this work is eminently worthy of public attention, it is in the plea it makes for appropriation by Congress of sufficient money, out of the millions accumulated in the treasury from inventors' fees in excess of expenses, to enable the Patent Office to prepare and publish classified

abridgments of the patents already granted, and to adequately remunerate a competent examining corps.

If a portion of the attention, energy and time now expended in Congress in cultivating the opportunities of political placemen could be devoted to the material interests fostered by the patent laws, such action might be hoped for, but the inventors and patentees have no lobby. Mr. Knight is working ably in the right direction in a good cause, in which the Franklin Institute has distinctly and repeatedly defined its position; he deserves the hearty co-operation of every intelligent citizen, and should succeed. S. L. W.

Prof. R. Koch's Method to Cure Tuberculosis. Popularly treated by Dr. Max Birnbaum. Translated from the German. Milwaukee, Wis., H. E. Haferkorn, 1891.

The translator, in his preface, makes the cheering announcement that consumption can be cured, presumably by Koch's lymph. This announcement is as yet premature, for although "'tis a consummation devoutly to be wished," the statement is scarcely sustained by the results of the many practical tests that have been made.

The book is a very interesting and readable one, and without being at all verbose, is one of the most complete essays on tuberculosis and its ravages, and one that may warmly be recommended to the student of medicine, since the author states clearly and concisely the nature of the dread malady together with the parts most frequently attacked by it. While not agreeing with the author in all his ideas with regard to the inception of tuberculosis, the writer can, however, most cordially agree with him and recommend his ideas regarding the hygienic measures which he advises for the prevention of the development of, and as assistants to, the cure of the disease. Means which tend to build up the physical health where a predisposition to this disease exists, act upon the same principle as a reinforcement to an army which is being besieged by an enemy—whichever side is the stronger must hold the other in check; and in this almost universal and dread disease, it is easier to keep the disease from developing by avoiding any exciting cause than to cure when it once asserts its power; an ounce of prevention in this particular instance being worth many pounds of attempted cure. G.

Franklin Institute.

[*Proceedings of the stated meeting, held Wednesday, Nov. 18, 1891.*]

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, November 18, 1891.

Mr. JOS. M. WILSON, President, in the chair.

Present, seventy-two members and twelve visitors.

Additions to membership since last report, seventeen.

The Secretary read a letter from Prof. George Forbes, of London, England, accepting election as an honorary member; also, one from Mr. J. C. Trautwine, Jr., accepting election to the Board of Managers, to fill the unexpired term of John J. Weaver, deceased.

Mr. B. E. Fernrow, Chief of the Division of Forestry, Department of Agriculture, read a paper on the Government Timber Tests at present being undertaken in the Forestry Division of the Department, describing the objects to be accomplished, the need of such investigation to furnish reliable data regarding the properties of our various timbers, and for the information of all who require to use wood in building, engineering and manufacturing, and describing the plan and methods proposed for carrying on the work. The paper was illustrated by the exhibition of charts and photographs of test pieces. The paper was referred for publication.

Mr. H. Reed exhibited and described a series of photographs, showing the progress of the work of construction upon the terminal and elevated railway of the Philadelphia and Reading Railroad in Philadelphia.

The Secretary presented a series of views of the buildings of the World's Columbian Exposition, to be held in Chicago in 1893. He exhibited also a view of the projected suspension bridge over the North or Hudson River at New York, the construction of which is contemplated by the North River Bridge Company. This bridge is intended to carry across the river and directly into the metropolis, the tracks of the ten or more railroads terminating in Jersey City, and would afford much needed relief in the transfer of freight across the North River. On account of the great increase of the traffic of the railroads at this location, the present methods of transfer by barges is found to be entirely inadequate. The design of this bridge contemplates a suspension structure crossing the river with a single span of about 3,000 feet and providing for fourteen railway tracks to accommodate the heaviest traffic.

Mr. W. N. Jennings continued the exhibition of his series of local pictures.

Adjourned. WM. H. WAHL, *Secretary.*

Summary of Meteorological Observations taken during the Year 1891, at the Pennsylvania State Weather Service Station, Emporium, Cameron County, 1,300 feet above tide, by T. B. Lloyd, Voluntary Observer.

Months, 1891.	Temperature.				Precipitation.			Weather.			Wind.		
	Highest.	Lowest.	Average.	Average range.	Rain and melted snow.	Rainy days.	Snow in inches.	Clear.	Fair.	Cloudy.	1891.	1890.	1889.
January,	51°	3°	30°	16°	3.47	9	1	4	8	19	NW	W	W
February,	61°	4°	34°	18°	4.56	13	6½	4	9	15	W	W	W
March,	62°	*4°	36°	19°	5.12	11	16½	7	8	15	E	W	W
April,	83°	17°	48°	28°	2.33	8	...	12	10	8	W	W	W
May,	83°	25°	60°	30°	1.06	5	...	12	7	12	NW	W	W
June,	92°	39°	68°	29°	4.45	12	...	15	8	7	NW	W	W
July,	90°	39°	69°	25°	8.46	12	...	12	8	11	W	W	NW
August,	92°	43°	68°	23°	5.10	14	...	3	20	8	E	NW	NW
September,	88°	38°	66°	26°	1.17	9	...	18	7	5	W	NW	W
October,	85°	23°	48°	23°	3.48	8	...	11	7	13	W	NW	NW
November,	66°	9°	39°	18°	4.01	12	2½	7	3	20	W	W	W
December,	58°	8°	37°	20°	4.96	11	2¾	11	8	12	W	NW	W
					48.37	124	29	116	103	145	...	...	...

* Below zero.

Summaries for 1889, 1890 and 1891.

Temperature.

Annual mean temp., 1889, ... 50.5°
Annual mean temp., 1890, ... 51.2
Annual mean temp., 1891, ... 50.2
Highest temp., July, 1889, ... 93
Highest temp., July, 1890, ... 94
Highest temp., June and August, 1891, ... 92
Lowest temp., February, 1889, below zero, . . 20
Lowest temp., March, 1890, below zero, . . . 13
Lowest temp., March, 1891, below zero, . . . 4
Extreme annual range temp., 1889, ... 113
Extreme annual range temp., 1890, ... 107
Extreme annual range temp., 1891, ... 96
Average monthly range temp., 1889, ... 22.8
Average monthly range temp., 1890, ... 23
Average monthly range temp., 1891, ... 23

Precipitation.

(In inches and hundredths.)

Rain and melted snow, 1889, ... 47.89
Rain and melted snow, 1890, ... 63.26
Rain and melted snow, 1891, ... 48.37
Average monthly precipitation, 1889, ... 3.99
Average monthly precipitation, 1890, ... 5.27
Average monthly precipitation, 1891, ... 4.03
Greatest monthly precipitation, 1889, May, . 8.04
Greatest monthly precipitation, 1890, May, . 9.61
Greatest monthly precipitation, 1891, July, . 8.46
Least monthly precipitation, 1889, March, . . 1.44
Least monthly precipitation, 1890, November, 2.16
Least monthly precipitation, 1891, May, . . . 1.06
Greatest daily rainfall, 1889, May 31, ... 5.85
Greatest daily rainfall, 1890, September 10, . 2.41
Greatest daily rainfall, 1891, July 23, ... 2.25

Wind.

Prevailing wind, 1889, ... West.
Prevailing wind, 1890, ... West.
Prevailing wind, 1891, ... West.

Weather.

Number days rainfall, 1889, ... 119
Number days rainfall, 1890, ... 143
Number days rainfall, 1891, ... 124
Clear days, 1889, ... 105
Clear days, 1890, ... 92
Clear days, 1891, ... 116
Fair days, 1889, ... 121
Fair days, 1890, ... 107
Fair days, 1891, ... 103
Cloudy days, 1889, ... 139
Cloudy days, 1890, ... 166
Cloudy days, 1891, ... 145

Late and Early Frosts.

May 29.
May 18.
May 27.
Frost July 21, 1890.

September 23, 1889.
September 28, 1890.
September 30, 1891.

Snow Fall.

	Inches.
Winter of 1888 and 1889,	33
Winter of 1889 and 1890,	23
Winter of 1890 and 1891,	56½
Winter of 1891 and 1892 to January 16,	14¼
1889, February,	13½
1889, March,	3½
	17
1890, February,	8
1890, March,	14¾
	22¾
1891, February,	6½
1891, March,	16½
	23

Summary of Meteorological Observations taken during the year 1891, at the Pennsylvania State Weather Service Station, Girardville, Schuylkill county, Pennsylvania, 1,000 feet above tide, by E. C. Wagner, Voluntary Observer U. S. Signal Service.

Months.	Average pressure of atmosphere by barometer.	Temperature.			Precipitation.		Weather.			Predictions Verified.	
		Highest.	Lowest.	Average.	In inches and hundredths.	Number of days rain or snow fall.	Clear.	Fair.	Cloudy.	Weather.	Temperature.
January,	30.033 in.	53°	10°	32°	8.74	13	8	14	9	80 p. c.	86 p. c.
February,	30.053 in.	57°	10°	34°	4.36	13	8	8	12	88 "	88 "
March,	30.085 in.	53°	7°	30°	4.08	14	14	6	11	90 "	90 "
April,	29.982 in.	79°	23°	51°	3.54	10	19	4	7	84 "	88 "
May,	30.010 in.	85°	31°	58°	1.80	11	18	8	5	85 "	91 "
June,	29.936 in.	92°	40°	66°	3.70	10	23	4	3	86 "	85 "
July,	29.997 in.	90°	48°	69°	9.64	13	19	2	10	81 "	89 "
August,	29.960 in.	89°	38°	64°	9.47	10	9	11	11	85 "	92 "
September,	30.120 in.	84°	41°	63°	1.99	6	19	9	2	92 "	88 "
October,	30.080 in.	80°	27°	54°	3.77	8	14	10	7	85 "	92 "
November,	30.127 in.	63°	12°	37°	5.12	9	16	6	8	80 "	85 "
December,	30.142 in.	60°	8°	34°	6.23	10	15	8	8	86 "	90 "
					62.44	127	182	90	93	.....	.....

Highest reading of barometer, December 31st, ... 30.531 inches.
Lowest reading of barometer, January 22d, ... 29.429 inches.
Highest reading of thermometer, June 15th and 16th, ... 92°.
Lowest reading of thermometer, March 2d, ... 7°.
Range of thermometer during the year, ... 85°.
Total snow fall for the year, ... 42.75 inches.
Total precipitation for the year, ... 62.44 inches.
Average monthly precipitation, ... 5.203 inches.

Greatest monthly precipation, July, ... 9.64 inches.
Least monthly precipitation, May, ... 1.80 inches.
Greatest daily rainfall, August 23d, ... 3.90 inches.
Precipitation 1887, ... 48.73 inches.
Precipitation 1888, ... 62.62 inches.
Precipitation 1889, ... 70.27 inches.
Precipitation 1890, ... 64.03 inches.
Precipitation 1891, ... 62.44 inches.

ITATION.		NUMBER OF DAYS.			WIND.			
					PREVAILING DIRECTION.			
Snowfall.	Number of rainy days.	Clear.	Fair.	Cloudy.	7 a. m.	2 p. m.	9 p. m.	OBSERVERS.
Alleg	17	10	13	8	NW	NW	NW	Oscar D. Stewart, Ob. W'th. Bu.
Bedfo	13	6	19	6	SW	SW	SW	Miss E. A. G. Apple.
Berks	...	...	...	...	...	...	...	William Shipe.
Berk	...	...	...	...	...	...	...	Franklin Yager.
Blair,	16	...	...	...	...	...	...	Dr. Charles B. Dudley.
Blair,	12	7	17	6	NW	NW	NW	A. H. Boyle.
Blair,	11	18	5	8	W	W	W	Prof. J. A. Stewart.
Bradf	10	11	8	12	E	S	SW	Charles Beecher.
Bucks	9	14	4	13	NW	W	W	J. C. Hilsman.
Camb	16	5	15	11	...	...	...	E. C. Lorentz.
Came	12	12	8	11	NW	W	W	T. B. Lloyd.
Carbo	11	13	7	11	NW	...	NW	J. J. Boyd.
Centr	15	8	14	9	W	W	W	Prof. Wm. Freur.
Chest	17	14	7	10	NW	SE	E	Jesse C. Green, D. D. S.
Chest	16	11	11	9	W	W	W	W. T. Gordon.
Chest	12	10	12	9	NW	...	SE	Benj. P. Kirk.
Chest	17	10	9	12	NW	...	SE	Knowles Croskey.
Chest	...	...	...	...	...	...	...	Prof. Wm. F. Wickersham.
Clarlo	...	...	...	...	...	...	...	Rev. W. W. Deatrick.
Cleart	14	7	17	7	W	W	W	Nathan Moore.
Crawf	7	9	16	6	S	W	W	B. H. Metcalf.
Cumb	15	8	7	7	...	NW	...	J. E. Pague.
Daupl	14	10	11	10	W	...	W	Frank Ridgway, Ob. W'th. Bu.
Delaw	...	10	10	11	SE	SE	NW	Prof. Susan J. Cunningham.
Erie.*	11	12	10	9	S	...	S	Peter Wood, Ob. W'th. Bu.
Fayet	10	19	8	4	...	...	...	Wm. Hunt.
Fultor	12	14	10	7	...	...	...	T. F. Sloan.
Hunti	12	11	8	12	W	W	W	Prof. W. T. Swigart.
Lawre	12	8	14	9	W	W	W	W. T. Butz.
Leban	14	9	12	10	NE	SW	SW	Geo. F. Hayes, C. E.
Lehigl	14	8	12	11	SW	SW	SE	M. H. Boye, M. D.
Luzern	11	15	5	11	NE	...	SW	A. W. Betterly.
McKe	14	14	7	9	S	S	S	Armstrong & Brownell.
Montg	12	17	5	9	W	W	W	Chas. Moore, D. D. S.
Philad	13	9	6	16	NW	...	NW	L. M. Dey, Ob. W'th. Bu.
Philad	14	9	7	15	NE, NW	...	SE, SW	John Comly, 1529 Centennial av
Schuyl	13	19	2	10	W	W	W	E. C. Wagner.
Snyder	10	15	7	9	SE	NE	NE	J. M. Boyer.
Somer	10	10	7	14	NW	NW	NW	W. M. Schrock.
Tioga,	13	4	15	12	N	NW	NW	H. D. Deming.
Union,	14	13	12	6	SW	SW	SW	F. O. Whitman.
Warre	13	11	15	5	SW	SW	SW	William Loveland.
Wayne	13	10	9	12	W	W	W	Theodore Day.
Wayne	14	...	...	...	...	...	...	John Torry.
Westm	11	19	8	4	...	...	...	J. T. Ambrose.
Wyom	12	10	11	10	S	...	S	B. M. Hall.
York,*	15	6	11	4	NW	...	NW	Mrs. L. H. Grenewald.
Bucks,	15	8	12	11	NW	NW	NW	J. L. Heacock.
Bucks,	9	14	4	13	N	W	W	
Bradfo	13	9	13	9	SW	SW	SW	G. W. T. Warburton.
Clintor	13	10	15	6	W	W	W	Prof. J. A. Robb.

L. M. DEY, *Assistant Director.*

MONTHLY SUMMARY OF REPORTS *by Voluntary Observers of the Pennsylvania State Weather Service for July, 1891.*

County.	Station	Elevation above sea level (feet).	Barometer reduced to sea level. Mean.	Barometer. Highest.	Barometer. Lowest.	Temperature. Mean.	Maximum. Highest.	Maximum. Date.	Minimum. Lowest.	Minimum. Date.	Mean of maximum.	Mean of minimum.	Daily range. Mean.	Daily range. Greatest.	Daily range. Date.	Daily range. Least.	Daily range. Date.	Relative humidity.	Dew point.	Precipitation. Total inches.	Snowfall.	Number of rainy days.	Number of days. Clear.	Fair.	Cloudy.	Wind. Prevailing direction. 7 a. m.	2 p. m.	9 p. m.	Observers.
Allegheny.*	Pittsburg	847	30.040	30.10	29.82	70	89	14	52	26	79.9	60.2	19.7	28	12	7	18	64.4	57.2	7.85	...	17	10	13	8	NW	NW	NW	Oscar D. Stewart, Ob. W'th. Bu
Bedford.	Charlesville.	1,300	...	...	...	66.3	87	14	43	9	78.3	54.2	24.1	37	12	8	1	87.3	62.8	6.61	...	13	6	19	6	SW	SW	SW	Miss E. A. G. Apple.
Berks.*	Hamburg.	380	...	...	...	69	92	14	49	11	80.3	57.7	22.6	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	William Shipe.
Berk.*	Reading.	280	...	...	...	72.2	...	...	...	...	...	...	...	...	...	...	...	...	...	7.35	...	...	...	...	...	...	...	...	Franklin Yager.
Blair.	Altoona.	1,181	...	...	...	70.7	90	15	42	13	80.8	60.6	20.2	35	12	7	23	...	...	3.99	...	16	...	...	...	...	...	...	Dr. Charles B. Dudley
Blair.	Blue Knob.	2,500	...	...	...	65.9	89	13	50	9	76.5	59.9	16.6	18	12	14	18	...	...	6.20	...	12	7	17	6	NW	NW	NW	A. H. Boyle.
Blair.	Hollidaysburg.	943	...	...	...	67.9	92	14	42	28	82.1	54.7	27.4	48	13	10	1,18	76.5	60	4.38	...	11	18	5	8	W	W	W	Prof. J. A. Stewart
Bradford.	Wysox.	718	30.040	30.32	29.78	66.1	91	14	41	10	77.7	54.2	23.5	42	22	5	18	76.6	53.3	2.63	...	10	11	8	12	E	S	SW	Charles Beecher
Bucks.	Forks of Neshaminy.		...	...	...	70.7	...	...	...	...	...	...	...	...	...	...	...	...	...	4.44	...	9	14	4	13	NW	W	W	J. C. Hilsman
Cambria.*	Johnstown.	1,184	30.063	30.35	29.83	...	92	14	...	...	81.5	...	...	...	...	...	...	83.2	60.9	8.81	...	16	5	15	11	...	...	...	E. C. Lorentz
Cameron.	Emporium.	1,060	...	...	...	68.5	90	10	...	...	...	...	...	...	...	...	...	72.7	58	8.46	...	12	12	8	11	NW	W	W	T. B. Lloyd.
Carbon.*	Mauch Chunk.	550	...	...	...	66.9	89	14	46	11	76	53	23	39	12	7	30	...	...	7.88	...	11	13	7	11	NW	...	NW	J. J. Boyd.
Centre.	State College.	1,191	29.890	30.29	29.69	65.4	86	14	47	9, 10	75.2	56	19.2	33	12	5	1	73.6	56.2	5.65	...	15	8	14	9	W	W	W	Prof. Wm. Frear.
Chester.*	West Chester.	455	30.033	30.34	29.77	69.1	87	15	53	8, 9	78.2	61.1	17.1	27	12	6	2	75	...	10.11	...	17	14	7	10	NW	SE	E	Jesse C. Green, D. D. S.
Chester.	Coatesville.	380	...	...	...	71.5	90	15	49	11	80.3	58.2	22.1	34	12, 13	7	2	...	...	11.61	...	16	11	11	9	W	W	W	W. T. Gordon.
Chester.	Kennett Square.	275	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	10.21	...	12	10	12	9	NW	...	SE	Benj. P. Kirk.
Chester.*	Phœnixville.	183	30.040	30.30	29.97	70.3	87	14	53	7	79.6	60.6	19	31	7	5	30	80.2	63.5	8.96	...	17	10	9	12	NW	...	SE	Knowles Croskey
Chester.	Westtown.	350	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	Prof. Wm. F. Wickersham
Clarion.	Rimersburg.	1,500	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	Rev. W. W. Deatrick.
Clearfield.	Grampian Hills.	1,450	29.94	30.21	29.71	65.4	90	14	46	10	75.5	57.7	17.8	30	10	4	30	...	...	7.03	...	14	7	17	7	W	W	W	Nathan Moore.
Crawford.	Meadville.	1,300	29.97	30.26	29.76	64.1	86	14	39	27	76.1	51.6	24.5	43	12	11	18	...	...	2.77	...	7	9	16	6	S	W	W	B. H. Metcalf.
Cumberland.	Carlisle.	480	...	...	...	67.6	93	14	50	10	81.3	56.8	24.5	38	14	14	10	86	63	6.03	...	15	8	7	7	...	NW	...	J. E. Pague.
Dauphin.*	Harrisburg.	361	30.033	30.34	29.74	69.6	87	14, 15	52	5	78.9	60.6	18.3	29	12	9	1	71.9	59.6	8.40	...	14	10	11	10	W	...	W	Frank Ridgway, Ob. W'th. Bu.
Delaware.	Swarthmore College.	190	...	...	...	69.4	86	21	54	9	78.8	60.8	18	29	12	6	2	...	...	...	...	...	10	10	11	SE	SE	NW	Prof. Susan J. Cunningham
Erie.*	Erie.	681	30.000	30.30	29.73	66	87	13	47	27	73	59	14	23	27	5	8	68	55	2.66	...	11	12	10	9	S	...	S	Peter Wood, Ob. W'th. Bu
Fayette.	Uniontown.	1,000	...	...	...	68.7	90	14	46	26	79.5	58.5	21	39	22	5	8	...	...	5.75	...	10	19	8	4	...	...	...	Wm. Hunt.
Fulton.	McConnellsburg.	875	...	...	...	68.1	90	14	46	29	81	56.7	24.3	40	12	5	1	77.2	60.5	6.32	...	12	14	10	7	...	...	...	T. F. Sloan.
Huntingdon.	Huntingdon.	650	...	...	...	68.1	97	14	44	19	81	55.7	25.3	39	14	8	1	...	...	4.49	...	12	11	8	12	W	W	W	Prof. W. T. Swigart
Lawrence.	Newcastle.	932	...	...	...	67.9	91	14	40	9	77	52.9	25.1	42	10	10	18	...	...	4.40	...	12	8	14	9	W	W	W	W. T. Botz.
Lebanon.	Lebanon.	474	30.053	30.52	29.78	68.1	89	14	49	10	79.7	57.4	22.3	35	12	10	18	80	61.9	8.70	...	14	9	12	10	NE	SW	SW	Geo. F. Hases, C. E.
Lehigh.	Coopersburg.	520	...	...	...	68.1	88	15	52	11	77.8	59.5	18.3	32	12	7	30	...	...	6.07	...	14	8	12	11	SW	SW	SE	M. H. Bore, M. D.
Luzerne.*	Wilkesbarre.	575	...	...	...	68.1	97	15	45	17	79.3	56.9	22.4	43	17	12	18	...	...	6.28	...	11	15	5	11	NE	...	SW	A. W. Betterly
McKean.	Smethport.	1,500	...	...	...	64.6	89	14	39	10	76.2	51	25.2	41	10	8	18	...	...	...	...	14	14	7	9	S	S	S	Armstrong & Browne.
Montgomery.	Pottstown.	150	...	...	...	71.1	91	14	53	11	81.5	61.4	20.1	34	12	7	2	79.3	62.6	8.91	...	12	17	5	9	W	W	W	Chas. Moore, D. D. S.
Philadelphia.	Weather Bureau.	117	30.035	30.36	29.77	71.9	89	15	54	8	80	63.8	26.2	28	12	3	8	71.1	59.7	4.85	...	13	3	6	16	NW	...	NW	L. M. Dey, Ob. W'th. Bu.
Philadelphia.	Philadelphia.	120	30.040	30.36	29.78	72.4	91	15	54	9	81.4	63.2	18	28	12	6	2	77.7	63	5.89	...	14	9	7	15	NE, NW	...	SE, SW	John Comly, 1829 Centennial av
Schuylkill.	Girardville.	1,000	29.997	30.24	29.61	66.3	90	15	48	10	75.8	55.6	20.2	30	12	7	30	...	...	9.64	...	13	19	2	10	W	W	W	E. C. Wagner.
Snyder.	Selinsgrove.	445	30.010	30.28	29.83	68.5	90	14	40	31	80.6	43.3	31.3	39	21	21	8	86.8	70	6.69	...	10	15	7	9	SE	NE	NE	J. M. Boyer.
Somerset.	Somerset.	2,250	...	...	...	64.4	88	12, 13	40	9, 10	77.1	51.3	25.8	46	12	8	1	86.1	65.1	4.68	...	10	10	7	14	NW	NW	NW	W. M. Schrock
Tioga.	Wellsboro.	1,327	29.993	30.34	29.65	60.1	86	14	34	10	78.3	50	28.3	36	10	9	1	60.3	50.4	3.45	...	18	4	15	12	N	NW	NW	H. D. Deming.
Union.*	Lewisburg.	450	...	...	...	70.1	95	15	43	12	83.2	57	26.2	42	11	11	2	...	...	5.09	...	14	13	12	6	SW	SW	SW	F. O. Whitman.
Warren.	Columbus.	1,410	...	...	...	62.6	88	12	34	27	75.5	49.7	25.8	46	10	5	18	64.5	49.3	5.34	...	13	11	15	5	SW	SW	SW	William Loveland.
Wayne.	Dyberry.	1,100	...	...	...	63	90	13	40	28	75.3	50.2	25.1	43	6	6	3	...	...	3.88	...	13	10	9	12	W	W	W	Theodore Day.
Wayne.	Honesdale.	1,000	...	...	...	64.4	85	13	41	11	75	53.7	22.3	34	11	9	30	65	58.1	4.71	...	14	...	...	...	...	...	...	John Torry.
Westmoreland.	Ligonier.	1,750	...	...	...	69.2	89	14	41	10	80.2	53.2	27	42	11, 13	15	1	86	70	5.95	...	11	19	8	4	...	...	...	J. T. Ambrose.
Wyoming.	South Eaton.	660	...	...	...	65.6	86	14	48	10	75.3	56	19.3	33	12	5	18	...	...	4.88	...	12	19	11	10	S	...	S	B. M. Hall.
York.*	York.	385	29.992	30.26	29.79	70	90	14	50	10, 26	82	58.1	23.9	36	7	11	2	82.1	62.6	10.77	...	15	6	11	4	NW	...	NW	Mrs. I. H. Grenewald
Bucks.	Quakertown.	536	30.040	30.34	29.81	67.3	90	14, 15	46	11	79.9	58.6	21.3	38	12	12	2	...	...	7.29	...	15	8	12	11	NW	NW	NW	J. L. Heacock.
Bucks.	Rush Valley.		...	...	...	70.7	...	...	...	...	...	...	...	...	...	...	...	...	...	4.44	...	9	14	4	13	N	W	W	
Bradford.	Le Roy.	1,400	...	...	...	67.5	88	13, 14	48	31	74.8	59.5	15.3	27	22	4	1,18	...	...	3.95	...	13	9	13	9	SW	SW	SW	G. W. T. Warburton.
Clinton.	Lock Haven.	560	...	...	...	67.9	92	14	45	10	79	56	23	30	12	5	1,2,18	...	...	6.95	...	13	10	15	6	W	W	W	Prof. J. A. Robb.

* Observations taken at 8 a. m. and 8 p. m.

† Observations taken at 12 noon.

L. M. DEY, *Assistant Director.*

	Relative humidity.	Dew point.	Precipitation.			Number of Days			Wind.		
									Prevailing Direction.		
			Total inches.	Snowfall.	Number of days rainfall.	Clear.	Fair.	Cloudy.	7 a. m.	2 p. m.	9 p. m.
Allegh			1.60		11	7	14	10	NW		NW
Bedfo			5.51		12	10	14	7	SW	SW	SW
Berks,			6.30		10	8	11	12	W		
Blair,			3.13		10						
Blair,			5.40		14	8	16	7	NW	NW	NW
Bradf	79.5	62.0	4.26		12	11	14	6	S	W	S
Bradf	84.1	62.2	2.49		13	4	4	23	E	SW	SE
Bucks			4.33		13	3	17	11	SW	SW	SW
Bucks			4.90		12	7	8	16	N	NW	W
Cambr			8.02		14						
Camer			3.87		16	5	15	11	S	W, NW	S
Carbon			5.40		14	3	20	8	E		E
Centre			5.89		10				NW		NW
Cheste	77.3	59.3	5.40		16	7	17	7	NW	NW	NW
Cheste	81	65	8.85		16	10	8	13	NW	S	SW
Cheste			4.08		12	8	10	13	W	S	SW
Cheste			8.74		15	8	10	13	NW		NW
Clearf	85.8	67.2	8.37		14	6	7	18	NW		NW
Clinto			4.08		11	6	17	8	W	W	W
Crawf			4.40		11	10	12	9	W	W	W
Cumbe						8	18	5			
Dauph	88.5	66.7	5.53		12	5	16	10	SW	W	W
Delaw	76.8	63.1	5.20		11	6	12	13	E	E	E
Erie,*			7.54								
Fayett	71.0	58	1.96		11	4	15	12	NE	NE	NE
Fulton			3.85		12	16	11	4			
Hunti	80.4	64.3	4.82		11	8	16	7			
Leban			3.83		11	14	8	9	W		W
Lehigh	85.9	66.2	5.06		13	8	9	14	SW	SW	SW
Luzern			7.16		14	6	8	17	SE	SW	NW
McKea			3.46		8	18	5	8	NE		SW
Montg			5.15		7	15	7	9	S	S	S
Philad	84.0	67	7 01		12	11	11	9	W	W	W
Philad	77.0	64	4.22		14	6	11	14	SW	SW	SW
Schuy	83.3	67.1	5.30		14	5	13	13	SW	SW	SW
Snyde			9.47		10	9	11	11	W	W	W
Somer	88.2	66.7	7.18		12	8	10	13	SW	NW	NW
Tioga,	88	62	5.02		15	7	10	14	NW	NW	NW
Union	67.4	56	3.57		13	10	13	8	N	N	SW
Warre			9.42		6	7	15	9	SW		SW
Wayn	66	52	3.74		13	10	8	12	SW	SW	SW
Wayn			4.75		14	5	14	12	NW	W	SW
Westm	68.4	64.5	4.21		12						
Wyom	77	69	2.81		8						
York,			4.15		11	5	15	11	S		NW
Lawre	86.5	66.9	3.29		11	8	16	7	NW		NW
			1.43		6	6	18	7	SE	NW	SE

L. M. DEY, *Observer in Charge.*

Monthly Summary of Reports *by Voluntary Observers of the Pennsylvania State Weather Service for August, 1891.*

County	Stations.	Elevation above sea level (feet).	Barometer Reduced to Sea Level. Mean.	Highest.	Lowest.	Temperature. Mean.	Maximum. Highest.	Date.	Minimum. Lowest.	Date.	Mean of maximum.	Mean of minimum.	Daily Range. Mean.	Greatest.	Date.	Least.	Date.	Relative humidity	Dew point.	Precipitation. Total inches.	Snowfall.	Number of days rainfall.	Number of Days. Clear.	Fair.	Cloudy.	Wind. Prevailing Direction. 7 a. m.	2 p. m.	9 p. m.
Allegheny.*	Pittsburg	847	30.01	30.23	29.62	71.7	94	10	48	29	81	62.4	18.6	28	7	7	23			1.60		11	7	14	10	NW		NW
Bedford.	Charlesville	1,300				67.5	99	9	40	29	79.3	57.3	22	31	8	12	21			5.51		12	10	14	7	SW	SW	SW
Berks.*	Hamburg	380				71.3	97	10	50	29	81.4	61.2	20.2	31	14, 17	7	5			6.30		10	8	11	12	W		
Blair.*	Altoona	1,181				72.7	95	12	50	29	81.5	63.9	17.6	23	3, 30	9	4			3.13		10						
Blair.	Blue Knob	2,500				66.5														5.40		14	8	16	7	NW	NW	NW
Blair.	Hollidaysburg	947				68.5	94	10	39	29	83.3	54.5	28.8	38	7	16	4	79.5	62.0	4.26		12	11	14	6	S	W	S
Bradford.	Wysox	718				67	93	11	42	3, 29	78.4	56.1	22.3	37	1, 3	4	5	84.1	62.2	2.49		13	4	4	23	E	SW	SE
Bradford.	Le Roy	1,400				68.6	90	11	47	29	76	60.9	15.1	24	1, 3	6	4			4.33		13	3	17	11	SW	SW	SW
Bucks.	Forks of Neshaminy (Rush Valley)					72.5														4.90		12	7	8	16	N	NW	W
Bucks.	Quakertown (29 days)	536				71.2														8.02		14						
Cambria.*	Johnstown	1,184				70.5	94	9, 10, 11	43	29	82.1	58.2	24.9	37	1	7	23			3.87		16	5	15	11	S	W, NW	S
Cameron.	Emporium	1,030				67.6	92	9	43	29	79	56	23	36	1	11	21, 24			5.40		14	3	20	8	E		E
Carbon.*	Mauch Chunk	550				67.9	95	10, 11	46	1	79.8	58.8	21	34	1	5	30			5.89		10				NW		NW
Centre.	State College	1,191				68.3	92	11	45	30	78.4	58.4	20	28	1	9	23	77.3	59.3	5.40		16	7	17	7	NW	NW	NW
Chester.	West Chester	455				71.3	92	10, 11	53	29, 30	79.5	64.9	14.6	22	17	6	18	81	65	8.85		16	10	8	13	NW	S	SW
Chester.	Coatesville	380				71.2	97	11	51	1	82.4	62.1	20.3	34	17	8	3			4.08		12	8	10	13	W	S	SW
Chester.*	Kennett Square	275				70.4	85	10	56	30										8.74		15	8	10	13	NW		NW
Chester.	Phœnixville	183				72.8	94	10	52	29	80.7	64.8	15.9	24	14	6	5	85.8	67.2	8.37		14	6	7	18	NW		NW
Clearfield.	Grampian Hills	1,450				67.5	91	10	44	29	77.7	59.5	18.2	36	22	4	23			4.08		11	6	17	8	W	W	W
Clinton.	Lock Haven	560				69	95	10	45	29										4.40		11	10	12	9	W	W	W
Crawford.	Meadville	1,300				66.7	92	9, 10															8	18	5			
Cumberland.	Carlisle	480				70.8	96	11	49	29	82.7	62.1	20.6	28	10, 11	8	5	88.5	66.7	5.53		12	5	16	10	SW	W	W
Dauphin.*	Harrisburg	361	30.00	30.24	29.74	71.2	92	10	54	29	80.2	64.2	16	24	17	6	5	76.8	63.1	5.20		11	6	12	13	E	E	E
Delaware.	Swarthmore College	190				72.6	95	10	52	30										7.54								
Erie.*	Erie	681	29.98	30.21	29.55	68	89	9	51	29	75.7	61.3	14.4	22	16	7	28	71.0	58	1.96		11	4	15	12	NE	NE	NE
Fayette.	Uniontown	1,000				71	91	9, 10	45	29	80.6	60.5	20.1	27	8	7	21, 23			3.85		12	16	11	4			
Fulton.	McConnellsburg	875				70.3	95	10	44	29	82.9	59.7	23.2	32	10	11	24	80.4	64.3	4.82		11	8	16	7			
Huntingdon.*	Huntingdon	650				70.8	94	10	49	25, 30	82.3	59.2	23.1	34	14	11	24			3.83		11	14	8	9	W		W
Lebanon.	Lebanon	474	30.02	30.26	29.71	70.4	94	10	47	29	81.2	60.9	20.3	33	11	8	5	85.9	66.2	5.06		13	8	9	14	SW	SW	SW
Lehigh.	Coopersburg	520				69.9	94	11	52	1, 3	78.8	62.6	16.2	26	1	4	5			7.16		14	6	8	17	SE	SW	NW
Luzerne.	Wilkesbarre	575					96	10	45	29										3.46		8	18	5	8	NE		SW
McKean.	Smethport	1,590				65.8	90	10	42	29	78.6	54.1	24.5	36	17	11	24			5.15		7	15	7	9	S	S	S
Montgomery.	Pottstown	150				74.1	96	11	54	29	82.7	65.6	17.1	27	1	5	18	84.0	67	7.01		12	11	11	9	W	W	W
Philadelphia.*	Philadelphia Weather Bureau	117	30.00	30.24	29.71	74.3	97	10	54	30	82	66.6	15.4	23	10	7	18	77.0	64	4.22		14	8	11	14	SW	SW	SW
Philadelphia.	Philadelphia (Centennial avenue)	120	30.01	30.24	29.72	74.5	99	10	54	30	82.4	66.5	15.9	26	10	6	5	83.3	67.1	5.30		14	5	13	13	SW	SW	SW
Schuylkill.	Girardville	1,000	29.96	30.16	29.70	67.9	89	10	38	16	76	58	18	47	14	8	30			9.47		10	9	11	11	W	W	W
Snyder.	Selinsgrove	445	29.90	30.23	29.53	69	95	10	40	29	82.4	56.5	31.9	37	3	26	16	88.2	66.7	7.18		12	8	10	13	SW	NW	NW
Somerset.	Somerset	2,250				66.4	93	10	35	30	80.6	54.5	26.1	41	1	12	21	88	62	5.02		15	7	10	14	NW	NW	NW
Tioga.	Wellsboro	1,327		30.26	29.61	67.4	86	10	36	30	74.3	59.2	24.1	36	30	8	21	67.4	56	3.57		13	10	15	8	N	N	SW
Union.	Lewisburg	450				71.2	95	10	47	29	82.7	59.8	22.9	33	1	8	24			9.42		6	7	15	9	SW		SW
Warren.	Columbus	1,410				65.6	94	9	38	30	78	53.7	24.3	38	7	5	21	66	52	3.74		13	10	8	12	SW	SW	SW
Wayne.	Dyberry	1,100				65	94	11	40	1	77.6	53.6	24	43	17	8	30			4.75		14	5	14	12	NW	W	SW
Wayne.	Honesdale	1,000				67.5	88	11	44	3	77.2	57.8	19.4	32	17	7	30	68.4	54.5	4.21		12						
Westmoreland.	Ligonier (27 days)	1,750				68.9	92	10	40	29	82.3	55.5	26.8	39	16	9	24	77	69	2.81		8						
Wyoming.*	South Eaton	699				67.7	89	11	47	29	76.4	58.9	17.5	31	17	7	5			4.15		11	5	15	11	S		NW
York.	York	385	29.96	30.22	29.68	71.2	95	10	48	29	83	60.6	22.4	35	17	16	5	86.5	66.9	3.29		11	8	16	7	NW		NW
Lawrence.	New Castle	932				72.2	95	10	38	29	81.6	54.1	27.5	38	27	12	21			1.43		6	6	18	7	SE	NW	SE

* Observations taken at 8 a. m. and 8 p. m.

† Observations taken at 12 noon.

L. M. Dey, *Observer in Charge.*

C	RECIPITATION.		NUMBER OF DAYS				WIND.			
							PRAVAILING DIRECTION.			
		Total snowfall during month.	Clear.	Fair.	Cloudy.	Number of rainy days.	7 a. m.	2 p. m.	9 p. m.	OBSERVERS.
Alleg	0	. . .	15	10	5	7	NW	NW	NW	G. D. Stewart, Ob. W'th. Bu
Bedf	5	. . .	16	8	6	7	N	SW	SW	Miss E. A. G. Apple.
Berks	7	. . .	9	16	5	8	NW	SW	SW	Wm. Shipe.
Berks	7	. . .	. . .	. . .	. . .	8	. . .	. . .	. . .	F. Yager.
Blair	1	. . .	. . .	. . .	. . .	7	. . .	. . .	. . .	Dr. C. B. Dudley.
Blair	0	. . .	18	8	4	5	SW	SW	NW	A. H. Boyle.
Blair	6	. . .	22	4	4	5	S	W	S	Prof. J. A. Stewart.
Bradf	9	. . .	16	5	9	4	E	SW	SE	Charles Beecher.
Bradf		. . .	15	10	5	8	SW	SW	SW	G. W T. Warburton.
Bucks	1	. . .	15	12	3	4	S	S	S	L. Townsend.
Bucks	9	. . .	14	13	2	6	N	N	W	J. C. Hilsman.
Bucks	7	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	J. L. Heacock.
Camb	3	. . .	7	16	7	8	S	. . .	S	E. C. Lorentz.
Came	7	. . .	18	7	5	9	W	W	W	T. B Lloyd.
Carbo	7	. . .	17	8	5	6	. . .	. . .	. . .	J. J. Boyd.
Centr	0	. . .	18	8	8	8	W	W	W	Prof. W. Frear.
Chest	0	. . .	23	3	4	8	NW	SW	SE	J. C. Greene, D. D. S.
Chest	8	. . .	17	10	3	6	W	W	W	W. T. Gordon.
Chest		. . .	15	10	5	5	NW	. . .	NW	B. P. Kirk.
Chest	7	. . .	13	12	5	6	NW	. . .	SW	Knowles Croskey.
Clear	8	. . .	16	9	1	5	. . .	W	. . .	Nathan Moore.
Clinto	1	. . .	18	7	5	8	W	W	W	Prof. J. A. Robb.
Crawf		. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	Prof. J. H. Montgomery.
Cumb	5	. . .	16	11	3	6	NW	SW	W	J. E. Pague.
Daupl	5	. . .	13	11	6	8	W	W	W	F. Ridgway, Ob. W'th. Bureau.
Delaw	9	. . .	18	4	6	5	NW	. . .	S	Prof. Susan J. Cunningham.
Erie,	2	. . .	14	9	7	11	S	S	S	Peter Wood, Ob. W'th. Bureau.
Fayet	3	. . .	23	4	3	8	. . .	. . .	. . .	Wm. Hunt.
Fulto	5	. . .	19	8	3	5	. . .	. . .	. . .	Thos. F. Sloan.
Hunti	7	. . .	22	5	3	5	W	W	W	Prof. W. J. Swigart.
Lanca	8	. . .	14	9	1	3	SW	SW	SW	L. T. Lampe.
Lawre	4	. . .	19	8	3	6	SE	NE	S	W. T. Butz.
Leban	7	. . .	11	11	2	8	NE	SW	SW	G. F. Hayes, C. E.
Lehig	8	. . .	13	11	6	8	NE	SW	NE	Dr. M. H. Boye.
Luzer		. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	J. R. Wagner.
Luzer	0	. . .	22	2	6	5	NW	. . .	NW	A. W. Betterly, M. D.
McKe	5	. . .	22	4	4	7	SW	SW	SW	Armstrong & Brownell.
Monto	3	. . .	22	6	2	4	W	W	W	Chas. Moore, D. D. S.
Phila	0	. . .	17	7	6	7	NW	. . .	SW	L. M. Dey.
Phila	8	. . .	13	14	3	7	NW	SW	SW	John Comly.
Schuy	9	. . .	19	9	2	6	W	W	W	E. C. Wagner.
Snyde	2	. . .	20	7	3	8	NW	SE	NE	J. M. Boyer.
Somer	7	. . .	18	2	10	7	SW	SW	SW	Wm. Schrock.
Tioga	0	. . .	16	8	6	7	N	N	SW	H. D. Deming.
Union	0	. . .	19	7	4	4	W	W	W	F. O. Whitman.
Warre	6	. . .	19	6	5	9	SW	SW	SW	Wm. Loveland.
Wayn	7	. . .	13	13	4	6	NW	NW	NW	Theodore Day.
Wayn	3	. . .	. . .	. . .	. . .	7	. . .	. . .	. . .	John Torry.
Westm	7	. . .	22	3	2	6	. . .	. . .	. . .	J. T. Ambrose.
Wyom	5	. . .	16	9	5	6	S	. . .	S	B. M. Hall.
York.	8	. . .	21	6	3	6	NW	. . .	NW	Mrs. L. H. Grenewald.

L. M. DEY, *Observer in Charge.*

Monthly Summary of Reports *by Voluntary Observers of the Pennsylvania State Weather Service for September, 1891.*

County	Station	Elevation above sea level (feet).	Barometer reduced to sea level: Mean.	Barometer: Highest.	Barometer: Lowest.	Temperature: Mean.	Maximum: Highest.	Maximum: Date.	Minimum: Lowest.	Minimum: Date.	Mean of maximum.	Mean of minimum.	Daily range: Mean.	Daily range: Greatest.	Daily range: Date.	Daily range: Least.	Daily range: Date.	Relative humidity.	Dew point.	Precipitation: Total inches.	Precipitation: Total snowfall during month.	Number of days: Clear.	Number of days: Fair.	Number of days: Cloudy.	Number of rainy days.	Wind: Prevailing direction: 7 a. m.	2 p. m.	9 p. m.	Observers.
Allegheny *	Pittsburg	847	30.16	30.42	29.98	69.4	90	2	46	9	79.7	59	20.7	29	20	5	6	76	59.3	1.90	...	15	10	5	7	NW	NW	NW	G. D. Stewart, Ob. W'th B.
Bedford	Charlesville	1,300	...	...	...	63.1	88	18	37	9	78.1	51.1	27	38	18	10	5	81.8	58.1	4.55	...	16	8	6	7	N	SW	SW	Miss E. A. G. Apple
Berks.*	Hamburg	380	...	...	...	66.7	94	26	43	9	80.5	57.5	23.2	38	17	9	5	...	...	1.77	...	9	16	5	8	NW	SW	SW	Wm. Shipe
Berks.*	Reading	280	30	30.32	29.76	65.8	...	...	...	...	...	...	...	...	...	...	...	...	...	1.65	...	...	...	...	8	...	...	...	F. Yager.
Blair	Altoona	1,181	...	...	...	69.2	86	27, 28	47	10, 30	78.6	59.8	18.8	26	28	5	6	...	...	2.71	...	7	...	...	7	...	...	...	Dr. C. B. Dudley.
Blair	Blue Knob	2,500	...	...	...	62.9	84	17, 18, 22	36	9, 10	...	...	...	18	18	12	9	...	...	2.70	...	18	8	4	5	SW	SW	NW	A. H. Boyle.
Blair	Hollidaysburg	947	...	...	...	64.5	91	17, 26	36	9, 30	81	50	31	42	17	9	5	78.8	58	2.16	...	22	4	4	5	S	W	S	Prof. J. A. Stewart.
Bradford	Wysox	718	30.16	30.44	29.91	64.1	87	18	37	9	76.2	52.3	23.9	37	17	8	5	86	59.9	1.79	...	16	5	9	4	E	SW	SE	Charles Beecher.
Bradford	Le Roy	1,400	...	...	...	65.3	87	25	42	30	74.3	56.4	17.9	31	17	9	6	...	...	2	...	15	10	5	8	SW	SW	SW	G. W. T. Warburton
Bucks	Hulmeville	...	30.09	30.35	29.80	66.5	90	26	48	10, 11	79.1	56.7	22.4	30	17	10	6	...	...	2.71	...	15	12	3	4	S	S	S	L. Townsend.
Bucks	Forks of Neshaminy (Rush Valley)	...	...	...	...	66.5	...	...	...	...	...	...	...	...	...	...	...	...	...	3.09	...	14	13	2	6	N	N	W	J. C. Hilsman
Bucks	Quakertown	536	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	1.17	...	...	...	...	...	...	...	...	J. L. Heacock
Cambria.*	Johnstown	1,184	30.20	30.50	30.06	67.4	92	17, 21	42	9, 10	81.5	53.7	27.8	38	20	12	30	88.2	63.4	1.83	...	7	16	7	8	S	...	S	E. C. Lorentz
Cameron	Emporium	1,030	...	...	...	66.5	88	21	38	30	77.4	51.7	25.7	42	17	7	5	...	...	1.17	...	18	7	5	9	W	W	W	T. B. Lloyd.
Carbon	Mauch Chunk (28 days)	550	...	...	...	66.4	91	18	40	10	78.2	54.5	23.7	43	18	9	5	...	...	1.57	...	17	8	5	6	...	...	...	J. J. Boyd.
Centre	State College	1,191	30.12	30.39	29.83	65.4	86	21	40	9	76.2	54.9	21.3	33	17	6	5	74.3	58.2	2.20	...	18	8	8	8	W	W	W	Prof. W. Frear.
Chester	West Chester	455	30.14	30.41	29.87	68.2	90	26	46	9	77.7	60.6	17.1	26	17	8	8	...	...	4.30	...	23	3	4	8	NW	SW	SE	J. C. Greene, D. D. S.
Chester	Coatesville	380	...	...	...	67.4	94	26	43	9	81.6	56.2	25.4	39	17	13	8	...	...	3.38	...	17	10	3	6	W	W	W	W. T. Gordon.
Chester	Kennett Square	375	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	5	...	15	10	5	5	NW	...	NW	B. F. Kirk
Chester	Phoenixville	183	30.16	30.43	29.92	68.9	89	26	42	11	78.4	58.7	19.7	33	11	10	8.29	85.6	62.5	2.67	...	13	12	5	6	NW	...	SW	Knowles Croskey
Clearfield	Grampian Hills	1,450	...	...	...	64	84	26	38	9, 10	75.8	55.5	20.3	36	10	6	6	...	...	2.38	...	16	9	1	5	...	W	...	Nathan Moore.
Clinton	Lock Haven	560	...	...	...	66	91	18	40	9	80.4	54.1	26.3	37	23	5	5	...	...	3.41	...	18	7	5	8	W	W	W	Prof. J. A. Robb
Crawford	Meadville	1,300	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	Prof. J. H. Montgomery
Cumberland	Carlisle	480	...	...	...	68.4	92	26	43	10	82.8	57.2	25.6	36	17	11	5	88.6	64.2	1.05	...	16	11	3	6	NW	SW	W	J. E. Pague.
Dauphin	Harrisburg	361	30.16	30.43	29.93	69.4	88	26	50	10	78.7	60.2	18.5	30	17	5	29	76	59.4	1.75	...	13	11	6	8	W	W	W	F. Ridgway, Ob. W'th. Bureau
Delaware	Swarthmore College (28 days)	190	30.15	30.32	29.97	69.7	91	26	47	9	79.5	58.9	20.6	30	21	14	3	82.1	63.6	2.89	...	18	4	6	5	NW	...	S	Prof. Susan J. Cunningham
Erie.*	Erie	681	30.13	30.40	29.91	66	85	17	48	11	72.8	58.7	14.1	25	11	4	6	74	56	2.82	...	14	9	7	11	S	S	S	Peter Wood, Ob. W'th Bureau
Fayette	Uniontown	1,000	...	...	...	68.6	88	24	41	9	78.6	56.3	22.3	30	10	11	6	...	...	2.23	...	23	4	3	8	...	...	...	Wm. Hunt.
Fulton	McConnellsburg	875	...	...	...	66	92	18	39	9	81.5	53.8	27.7	38	18	9	5	80.2	60	2.65	...	19	8	3	5	...	...	...	Thos. F. Sloan.
Huntingdon	Huntingdon	650	...	...	...	67.5	92	21, 25	39	9	81.4	55.9	27.5	41	17	11	6	...	...	2.07	...	22	5	3	5	W	W	W	Prof. W. J. Swigart
Lancaster	Lancaster (24 days, 7th to 30th)	413	30.17	30.40	29.87	67.3	89	22	46	30	79.3	55.5	23.8	31	21	10	8	79.6	60.4	.28	...	14	9	1	3	SW	SW	SW	L. T. Lampe.
Lawrence	Newcastle	932	...	...	...	69.8	91	21	36	10	79.6	50.8	28.8	39	2	9	21	...	...	3.34	...	19	8	3	6	SE	NE	S	W. T. Butz.
Lebanon	Lebanon	474	30.16	30.44	29.92	66.9	91	22, 26	40	9	80.3	55.5	24.8	40	18	12	5	82.9	61.2	1.07	...	11	11	2	8	NE	SW	SW	G. F. Hayes, C. E.
Lehigh	Coopersburg	520	...	...	...	66.5	86	26	45	9	76.4	58.6	27.8	29	17	8	5	...	...	2.08	...	13	11	6	8	NE	SW	NE	Dr. M. H. Boye.
Luzerne	Drifton	1,655	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	J. R. Wagner.
Luzerne.*	Wilkesbarre	575	...	...	...	68.3	91	26	44	10, 30	80.8	55.8	25	36	17	9	1	...	...	1.70	...	22	2	6	5	NW	...	NW	A. W. Betterly, M. D.
McKean	Smethport	1,500	...	...	...	60.8	89	18	37	30	74.1	47.6	27.5	45	17	8	4	...	...	2.45	...	22	4	4	7	SW	SW	SW	Armstrong & Brownell
Montgomery	Pottstown	150	...	...	...	70.1	90	26	47	9	80.5	59.8	20.7	32	17	8	5	80.4	61.9	2.63	...	22	6	2	4	W	W	W	Chas. Moore, D. D. S.
Philadelphia	Philadelphia Weather Bureau	117	30.16	30.42	29.88	71.6	91	26	51	9	80.3	63	17.3	26	18	6	8	76.9	60.6	1.90	...	17	7	6	7	NW	...	SW	L. M. Dey.
Philadelphia	Philadelphia (Centennial avenue)	129	30.16	30.42	29.88	71.6	91	18, 26	49	9	80.6	62.6	18	26	21	6	8	81.5	62.4	1.88	...	13	14	3	7	NW	SW	SW	John Comly
Schuylkill	Girardville	1,000	30.12	30.34	29.97	64.4	84	18	41	9	74.6	54.1	20.5	35	18	8	20	...	...	1.99	...	19	9	2	6	W	W	W	E. C. Wagner.
Snyder	Selinsgrove	445	30.14	30.40	29.65	66.5	92	4	36	17, 19	80.5	45.9	34.6	52	18	14	29	88	63.4	4.12	...	20	7	3	8	NW	SE	NE	J. M. Boyer.
Somerset	Somerset	2,250	...	...	...	62.2	94	17	33	9	79	49.2	29.8	45	17	15	5.7	88.7	59.7	4.17	...	18	2	10	7	SW	SW	SW	Wm. Schrock.
Tioga	Wellsboro	1,327	30.12	30.46	29.86	60.8	86	19, 24	32	30	74.7	47	27.7	32	9	10	29	68.7	52.3	2.30	...	16	8	6	7	N	N	SW	H. D. Deming.
Union.*	Lewisburg	450	...	...	...	...	93	18	40	9	...	...	...	36	17	15	5	...	...	2.60	...	19	7	4	4	W	W	W	F. O. Whitman.
Warren	Columbus	1,410	...	...	...	62.8	88	17, 24	32	30	76.8	49.8	27	42	10	5	6	65	48	2.46	...	19	6	5	9	SW	SW	SW	Wm. Loveland.
Wayne	Dyberry	1,100	...	...	...	60.8	87	21	34	9	76.1	49.3	26.8	43	17	4	5	...	...	2.37	...	13	13	4	6	NW	NW	NW	Theodore Day
Wayne	Honesdale	1,000	...	...	...	63.4	82	26	38	9	73.8	52.9	20.9	34	17	5	5	69.5	59	2.53	...	...	...	...	7	...	...	...	John Torry.
Westmoreland	Ligonier	1,750	...	...	...	66.7	90	27	37	9	82	51.4	30.6	40	21	13	6	...	...	2.17	...	22	3	2	6	...	...	...	J. T. Ambrose.
Wyoming.*	South Eaton	660	...	...	...	63.3	87	18	40	9	72.9	53.8	19.1	28	18	7	5	...	...	1.35	...	16	9	5	6	S	...	S	B. M. Hall.
York *	York	385	30.13	30.34	29.95	69	92	26	40	9	81.8	56.2	25.6	39	17	6	29	88.1	67	1.88	...	21	6	3	6	NW	...	NW	Mrs. L. H. Grenewald

* Observations taken at 8 a. m. and 8 p. m.

† Observations taken at 12 noon

L. M. Dey, *Observer in Charge.*

er Service for October, 1891.

C	IPITATION.		NUMBER OF DAYS			WIND.			OBSERVERS.
	PTH OF NOW.					PREVAILING DIRECTION.			
	31st.	Number of days rainfall.	Clear.	Fair.	Cloudy.	7 a. m.	2 p. m.	9 p. m.	
Allegh	T	10	9	14	8	W	.....	W	O. D. Stewart, Obs. Weather Bureau.
Berks,	...	8	6	14	11	...	.....	...	William Shipe.
Berks,	...	...	...	...	...	...	.....	...	F. Yager.
Blair,	...	...	...	...	...	...	.....	...	Dr. C. B. Dudley.
Blair,	T	9	8	10	13	NW	NW	NW	A. H. Boyle.
Blair,	...	11	13	8	10	W	W	W	Prof. J. H. Stewart.
Bradf	...	8	13	4	14	E	W	NW	Charles Beecher.
Bradf	...	10	9	10	12	SW	SW	SW	G. W. T. Warburton.
Bucks	...	5	12	8	11	NW	NW	NE	L. Townsend.
Bucks	...	9	13	9	5	N	N	W	J. C. Hillsman.
Bucks	T	7	9	11	11	NE	NE, NW	NE	J. L. Heacock.
Cambr	T	10	9	11	11	S	.....	S	E. C. Lorentz.
Camer	...	8	11	7	13	W	E	W	T. B. Lloyd.
Carbo	...	...	...	...	...	...	.....	...	J. J. Boyd.
Centre	...	12	7	11	13	W	W	W	Prof. W. Frear.
Cheste	...	11	15	4	12	NW	NW	NW	J. C. Green, D. D. S.
Cheste	...	7	12	7	12	W	.....	W	W. T. Gordon.
Cheste	...	8	11	9	11	NW	.....	NW	B. P. Kirk.
Cheste	...	9	8	7	16	NW	.....	NW	Knowles Crosby.
Clearf	...	11	11	11	9	W	W	W	Nathan Moore.
Clinto	...	13	12	10	9	W	W	W	Prof. J. H. Robb.
Crawf	...	...	...	...	...	...	.....	...	Prof. J. H. Montgomery.
Cumbe	...	8	12	7	12	N	N	N	J. E. Pague.
Dauph	...	11	12	5	14	NW	NW	NW	F. Ridgeway, Obs. Weather Bureau.
Delaw	...	6	11	12	8	N	N	N	Prof. Susan J. Cunningham.
Erie,*	...	11	8	8	15	S	S	S	Peter Wood, Obs. Weather Bureau.
Fayett	I	6	19	5	7	...	.....	...	Wm. Hunt.
Fulton	...	4	15	6	10	N	N	NW	Thos. F. Sloan.
Hunti	...	6	15	7	9	W	.....	W	Prof. W. J. Swigart.
Lanca	...	9	11	11	9	NW	NW	NW	L. T. Lampe.
Lawre	...	8	12	7	12	SE	SE	SE	W. T. Butz.
Leban	T	10	11	9	11	SW	SW	SW	G. E. Hays, C. E.
Lehigh	...	6	12	7	12	NW	NW	NE	Dr. M. H. Boye.
Luzern	...	...	...	...	...	...	.....	..	J. R. Wagner.
Luzern	...	3	11	4	16	NW	.....	NW	H. W. Betterly.
McKea	...	...	...	...	...	...	.....	...	Armstrong & Brownell.
Montg	...	4	16	6	9	W	W	W	Charles Moore, D. D. S.
Philad	...	9	14	7	10	NW	NW	NW	L. M. Dey.
Philad	...	10	11	12	8	NW	NE	NW	John Comly.
Schuyl	...	8	14	10	7	W	W	W	E. E. Wagner.
Snyder	...	9	12	11	8	NW	NW	NW	J. M. Boyer.
Somer	...	6	12	3	16	NW	NW	NW	Wm. Schrock.
Tioga,	T	5	5	15	11	N	NW	NW	H. D. Deming.
Union,	...	4	14	9	8	NE	.....	NE	F. O. Whitman.
Warre	...	11	...	...	...	N	SW	SW	Wm. Loveland.
Wayne	T	8	8	12	11	NW	NW	NW	Theo. Day.
Wayne	...	4	...	...	...	...	.....	...	John Torrey.
Westm	...	9	12	11	8	...	.....	...	J. T. Ambrose.
Wyom	...	6	9	8	14	NW	.....	NW	B. M. Hall.
York.*	T	10	15	8	8	NW	.....	NW	Mrs. L. H. Grenewald.

L. M. DEY, *Observer in Charge.*

Monthly Summary of Reports *by Voluntary Observers of the Pennsylvania State Weather Service for October, 1891.*

County.	Station.	Elevation above sea level (feet).	Barometer Reduced to Sea Level. Mean.	Highest.	Lowest.	Temperature. Maximum. Mean.	Highest.	Date.	Minimum. Lowest.	Date.	Mean of maximum.	Mean of minimum.	Daily Range. Mean.	Greatest.	Date.	Least.	Date.	Relative humidity.	Dew point.	Precipitation. Total.	Depth of snow. 15th.	31st.	Number of days rainfall.	Number of Days. Clear.	Fair.	Cloudy.	Wind. Prevailing direction. 7 a. m.	2 p. m.	9 p. m.	Observers.
Allegheny.*	Pittsburg.	847	30.14	30.53	29.72	53.4	85	3	31	28	62.6	44.2	18.4	33	25	6	8	66.6	40	1.53		T	10	9	14	8	W		W	O. D. Stewart, Obs. Weather Bureau
Berks.	Hamburg.	380				52	89	3,4	24	29	62.4	41.5	20.9	35	30	7	20			2.69			8	6	14	11				William Shipe.
Berks.	Reading.	230																												F. Yeager.
Blair.†	Altoona (26 days).	1,181				55.5	82	5	35	12	61.8	45.2	16.6	25	25,29	7	13,16	58.5	39	2.54										Dr. C. B. Dudley.
Blair.	Blue Knob.	2,500					80	3	23	28				17	4	8	22,28			3.30		T	9	8	10	13	NW	NW	NW	A. H. Boyle.
Blair.	Hollidaysburg.	947				49	87	3	20	29	65	35	30	49	2	8	7	75.3	41.2	2.76			11	13	8	10	W	W	W	Prof. J. H. Stewart.
Bradford.	Wysox.	718	30.13	30.61	29.76	47.2	82	3,4	20	29	57.8	36.3	21.5	37	30	5	7	86.6	43.2	4.43			8	13	4	14	E	W	NW	Charles Beecher.
Bradford.	Le Roy.	1,400				48.1	83	3	25	12	57	39.2	17.8	33	1	4	7,27			4.25	T		10	9	10	12	SW	SW	SW	G. W. T. Warburton.
Bucks.	Hulmeville.		30.06	30.54	29.61	51.5	86	4,5	26	29	62.6	41.9	20.7	38	5	4	12			2.91			5	12	8	11	NW	NW	NE	L. Townsend.
Bucks (27 days).	Forks of Neshaminy (Rush Valley).					51														3.68			9	13	9	5	N	N	W	J. C. Hillsman.
Bucks.	Quakertown.	536	30.08	30.54	29.74	49.9	88	4	21	29	62.6	39	23.6	35	4	9	22	80.2	43.7	2.96		T	7	9	11	11	NE	NE,NW	NE	J. L. Heacock.
Cambria.*	Johnstown.	1,184	30.16	30.56	29.70	50.9	84	2	27	29	62.6	39.4	23.2	41	29	10	20			2.80		T	10	9	11	11	S		S	E. C. Lorentz.
Cameron.	Emporium.	1,030				48.2	85	3	23	29	59.9	36.5	23.4	41	30	6	20	46.5	29.7	3.48			8	11	7	13	W	E	W	T. B. Lloyd.
Carbon.*	Mauch Chunk.	550				47.1	88	4			60.6	38.8	21.8							2.89										J. J. Boyd.
Centre.	State College.	1,191	30.06	30.57	29.67	48.7	83	3,4	26	29	57.9	39.5	18.4	34	30	5	7	73.7	39.6	4.38			12	7	11	13	W	W	W	Prof. W. Frear.
Chester.	West Chester.	455	30.06	30.57	29.67	52.2	84	4	28	29	62.6	44.2	18.4	28	30	10	19	70	42	3.40			11	15	4	12	NW	NW	NW	J. C. Green, D. D. S.
Chester.	Coatesville.	380				50.5	90	4	21	29	64.9	39.6	25.3	44	30	4	19			3.46			7	12	7	12	W		W	W. T. Gordon.
Chester.*	Kennet Square.	275				50.5														3.16			8	11	9	11	NW		NW	B. P. Kirk.
Chester.	Phœnixville.	183	30.10	30.53	29.69	53	86	3,4	25	29	63.5	42.5	21	34	30	9	20	79.8	44.9	3.32			9	8	7	16	NW		NW	Knowles Crosby.
Clearfield.	Grampian Hills.	1,450	30.20	30.58	29.89	46	80	4	24	29	55.4	38.5	16.9	36	25	2	7,20			3.17			11	11	11	9	W	W	W	Nathan Moore.
Clinton.	Lock Haven.	560				50	89	4	25	29	61.4	38.7	22.7	37	31	4	20			3.73			13	12	10	9	W	W	W	Prof. J. H. Robb.
Crawford.	Meadville.	1,300				47.2																								Prof. J. H. Montgomery.
Cumberland.	Carlisle.	480				50.6	91	3	26	29	64.6	41.2	23.4	39	31	5	7,19	83.4	45.8	3.51			8	12	7	12	N	N	N	J. E. Pague.
Dauphin.*	Harrisburg.	361	30.12	30.68	29.70	52.4	85	4	32	29	60.8	44.1	16.7	33	30	6	7	70.8	41.7	2.87			11	12	5	14	NW	NW	NW	F. Ridgeway, Obs. Weather Bureau.
Delaware.	Swarthmore College.	190	30.06	30.46	29.63	52.1	87	4	25	9	62.9	44.5	18.4	30	29	9	20	74.8	43.9	3.75			6	11	12	8	N	N	N	Prof. Susan J. Cunningham.
Erie.*	Erie.	681	30.08	30.58	29.69	52	83	4	30	12	58.5	44.6	13.9	28	25	5	5	68	40	1.75			11	8	8	15	S	S	S	Peter Wood, Obs. Weather Bureau.
Fayette.	Uniontown.	1,000				52.9	84	4	30	29	62.8	43	19.8	34	26	2	27			2.99			6	19	5	7				Wm. Hont.
Fulton.	McConnellsburg.	875				50.6	88	3,4	23	29	62.6	38.9	23.7	44	30	7	7	79.1	43.8	3.39			4	15	6	10	N	N	NW	Thos. F. Sloan.
Huntingdon.	Huntingdon.	650				50.2	88	4	22	29	63	37.5	25.5	45	30	6	27			3.13			6	15	7	9	W		W	Prof. W. J. Swikart.
Lancaster.*	Lancaster—Franklin and Marshall College.	413	30.14	30.52	29.75	52	86	4	34	28	63.2	40.8	22.4	36	31	9	20	84.3	47	3.05			9	11	11	9	NW	NW	NW	L. T. Lampe.
Lawrence.	Newcastle.	392				54	86	3,4	24	28,29	62.5	36.1	26.4	40	25	6	27			.84			8	12	7	12	SE	SE	SE	W. T. Butz.
Lebanon.	Lebanon.	474	30.11	30.57	29.72	50.7	90	4	25	29	64	40.7	23.3	37	31	6	7	78.7	44.5	3.14		T	10	11	9	11	SW	SW	SW	G. E. Hays, C. E.
Lehigh.	Coopersburg.	520				50.6	83	4	27	29	60.7	42.8	17.9	28	31	9	7			2.74			6	12	7	12	NW	NW	NE	Dr. M. H. Boye.
Luzerne.	Drifton.	1,653																												J. R. Wagner.
Luzerne.*	Wilkesbarre.	575				52.2	75	12	22	28	60.8	43.7	17.1	38	31	6	1			1.63			3	11	4	16	NW		NW	H. W. Betterly.
McKean.	Smethport.	1,500																												Armstrong & Browne.
Montgomery.	Pottstown.	150				53.8	87	4	25	29	63.7	43.9	19.8	36	30	5	22	77.9	45	3.95			4	16	6	9	W	W	W	Charles Moore, D. D. S.
Philadelphia.*	Philadelphia Weather Bureau.	117	30.09	30.54	29.68	54.9	86	4	36	28	62.8	47	15.8	25	26	7	12	70.3	43.2	2.57			9	14	7	10	NW	NW	NW	L. M. Dey.
Philadelphia.	Philadelphia, Centennial avenue.	120	30.10	30.53	29.67	55.2	88	5	32	29	64.3	46.1	18.2	25	25,26	9	20	78.8	46	3.19			10	11	12	8	NW	NE	NW	John Comly.
Schuylkill.	Girardville.	1,000	30.08	30.40	29.54	48	80	4	27	29	56.3	39.1	20.2	36	29	3	12			3.77			8	14	10	7	W	W	W	E. E. Wagner.
Snyder.	Selinsgrove.	445	30.11	30.54	29.83	50.2	79	5	24	29	62.3	40.8	21.5	36*	31	7	19	84	46	4.46			9	12	11	8	NW	NW	NW	J. M. Boyer.
Somerset.	Somerset.	2,250				47.8	88	2,3	22	29	61.1	34.7	27.4	38	3	18	12	89.3	45.1	2.45			6	12	3	16	NW	NW	NW	Wm. Schrock.
Tioga.	Wellsboro.	1,327	30.08	30.61	29.74	44.2	82	4	18	19	51.4	35.7	15.7	38	29	5	27	82.2	68.4	2.44		T	5	5	15	11	N	NW	SW	H. D. Deming.
Union.*	Lewisburg.	450				51.2	82	3	27	25	62.7	39.7	23	36	31	10	20			3.75			4	14	9	8	NE		NE	E. O. Whitman.
Warren.*	Columbus.	1,410				47	84	3,4	19	13	57.9	36	21.9	49	13	1	27			1.95			11				N	SW	SW	Wm. Loveland.
Wayne.	Dyberry.	1,100				44.1	84	4	15	29	56.8	33.6	23.2	42	31	5	7			3.41		T	8	8	12	11	NW	NW	NW	Theo. Day.
Wayne.	Honesdale.	1,000				47.4	78	4	19	29	57	37.9	19.1	36	30	4	7	61.1	40.5	3.74			4							John Torrey.
Westmoreland.	Ligonier.	1,750				50.5	87	4	21	29	63.5	37.2	26.3	44	29	4	27			.88			9	12	11	8				J. T. Ambrose.
Wyoming.*	South Eaton.	660				48.6	83	4	22	29	58.1	39.1	19	33	31	7	7			3.71			5	9	8	14	NW		NW	B. M. Hall.
York.*	York.	385	30.05	30.45	29.78	50.1	87	4	20	29	63.3	36.3	27	42	30	7	7	81.1	44.7	3.20		T	10	15	8	8	NW		NW	Mrs. L. H. Grenewald.

* Observations taken at 8 a. m. and 8 p. m.

† Observations taken at 12 noon.

L. M. DEY, Observer in Charge.

r Service for November, 1891.

	ECIPI-TION.	NUMBER OF DAYS				WIND.			
						PREVAILING DIRECTION.			
	Snow.	With rain.	Clear.	Fair.	Cloudy.	7 a. m.	2 p. m.	9 p. m.	OBSERVERS.
Alle	1	14	3	7	20	SE	....	SW	Oscar D. Stewart, Ob. W'th. Bu.
Berk	8	6	5	13	12	....	....	....	Wm. Shipe.
Berk	8	11	....	....	....	....	....	....	Franklin Yager.
Blai	9	9	....	....	....	....	....	....	Dr. Charles B. Dudley.
Blai	9	11	5	11	14	NW	NW	NW	A. H. Boyle.
Blai	6	8	4	8	18	W	W	W	Prof. J. A. Stewart.
Brad	3	9	7	4	19	E	NW	SE	Charles Beecher.
Brad	4	13	6	4	20	SW	SW	SW	Geo. W. T. Warburton.
Buck	2	4	15	5	10	NW	....	N	L. Townsend.
Buck	4	9	14	7	5	N	N	N	J. C. Hilsman.
Buck	1	10	8	17	5	SW	NW	NW	J. L. Heacock.
Cam	1	15	1	11	18	S, SW	....	S	E. C. Lorentz.
Cam	1	12	7	3	20	W	W	W	T. B. Lloyd.
Cent	1	7	2	11	17	W	W	W	Prof. Wm. Frear.
Ches	9	11	17	3	10	NW	NW	NW	Jesse C. Green, D. D. S.
Ches	8	9	14	6	10	W	W	W	W. T. Gordon.
Ches	9	11	13	5	12	NW	....	NW	Benj. P. Kirk.
Ches	9	12	10	6	14	NW	....	NW	Knowles Croskey.
Ches	1	....	....	....	....	....	....	....	T. H. Haines.
Clea	5	14	3	12	15	W	W	W	Nathan Moore.
Clin	2	9	13	4	13	W	W	W	Prof. John A. Robb.
Craw	....	....	5	10	15	....	....	....	E. C. Williams.
Cum	0	10	11	9	10	SE	NW	NW	J. E. Pague.
Dau	5	12	8	13	9	W	....	W	Frank Ridgway, Ob. W'th. Bu.
Dela	2	6	14	6	10	NW	NW	NW	Prof. Susan J. Cunningham.
Erie	9	20	2	6	22	S	....	S	Peter Wood, Ob. W'th. Bu.
Faye	5	10	11	10	9	....	....	....	Wm. Hunt.
Fult	3	5	10	6	7	W	NW	W	Thomas F. Sloan.
Hun	9	7	8	11	11	W	....	W	Prof. J. A. Swigart.
Land	9	5	11	13	6	NW	....	NW	Lewis T. Lampe.
Law	2	7	4	17	19	SE	SE	SE	Wm. T. Butz.
Leba	4	10	7	13	10	NE	SW	NE	Geo. F. Hays, C. E.
Leh	7	10	11	8	11	NW	NW	NE	Dr. M. H. Boye.
Luze	8	5	8	12	8	....	....	....	J. R. Wagner.
Luze	3	9	12	1	17	NW	....	NW	A. W. Betterly.
McK	....	....	....	....	....	....	....	....	Armstrong & Brownell.
Mon	8	5	17	5	8	W, NW	W	W	Charles Moore, D. D. S.
Phil	0	9	11	9	10	NW	....	NW	Luther M. Dey, Observer.
Phil	6	9	13	10	17	NW	NW	NW	John Comly.
Schu	2	9	16	6	8	W	W	W	E. C. Wagner.
Snyd	5	8	7	10	13	NW	NW	NW	J. M. Boyer.
Some	5	7	3	6	21	SW	SW	SW	W. M. Schrock.
Tiog	1	12	2	9	19	N	S	S	H. D. Deming.
Union	5	7	11	9	10	SW	SW	SW	F. O. Whitman.
Warr	0	20	2	8	20	SW	SW	SW	Wm. Loveland.
Way	5	8	6	13	11	NW	NW	NW	Theodore Day.
Way	2	8	....	....	....	....	....	....	John Torrey.
West	3	12	9	12	9	....	....	....	J. T. Ambrose.
Wyo	4	8	7	4	19	S	....	S	Benj. M. Hall.
York	3	10	14	5	11	NW	....	NW	Mrs. L. H. Grenewald.

L. M. DEY, *Observer in Charge.*

Monthly Summary of Reports *by Voluntary Observers of the Pennsylvania State Weather Service for November, 1891.*

County	Station	Elevation above sea level (feet).	Barometer Reduced to Sea Level. Mean.	Highest.	Lowest.	Temperature. Maximum. Mean.	Highest.	Date.	Minimum. Lowest.	Date.	Mean of maximum.	Mean of minimum.	Daily Range. Mean.	Greatest.	Date.	Least.	Date.	Relative humidity.	Dew point	Precipitation. Total.	Snow.	Number of Days. With rain.	Clear.	Fair.	Cloudy.	Wind. Prevailing Direction. 7 a. m.	2 p. m.	9 p. m.	Observers
Allegheny.*	Pittsburg.	847	30.15	30.64	29.26	42.2	56	9	16	18	49.6	35	14.6	32	8	5	1	66	30.3	2.61	...	14	3	7	20	SE	...	SW	Oscar D. Stewart. Ob. W'th. Bu
Berks.*	Hamburg.	580	...	...	...	39.8	63	23	13	30	49.5	30.1	19.4	35	8	7	29	...	...	1.48	...	6	5	13	12	...	...	...	Wm. Shipe.
Berks.*	Reading.	280	...	...	...	40.1	...	...	...	...	...	...	...	...	...	...	...	...	...	1.38	...	11	...	...	...	...	...	...	Franklin Yager.
Blair.	Altoona.	1,181	...	...	...	44.9	69	1	11	30	53.6	36.2	17.4	37	29	5	22	59.3	31	1.89	...	9	...	...	...	...	...	...	Dr. Charles B. Dudley.
Blair.	Bloe Knob.	2,500	...	...	...	33.1	63	9	10	18	...	...	...	...	...	...	...	...	...	2.29	11	11	5	11	14	NW	NW	NW	A. H. Boyle.
Blair.	Hollidaysburg.	947	...	...	...	38.6	63	9	9	19	49.8	26.9	22.9	43	9	8	3	74.8	31.5	2.76	2.5	8	4	8	18	W	W	W	Prof. J. A. Stewart.
Bradford.	Wysox.	718	30.14	30.74	29.25	37.3	64	23	14	30	45.5	28.2	17.3	34	17	6	29	79.4	32.5	2.73	1	9	7	4	19	E	NW	SE	Charles Beecher.
Bradford.	Le Roy.	1,400	...	...	...	36.4	61	23	8	30	43.8	28.1	14.7	29	28	5	3	...	...	3.24	3	13	6	4	20	SW	SW	SW	Geo. W. T. Warburton.
Bucks.	Holmeville.	...	30.19	30.85	29.29	41.6	66	10	15	30	51.6	31.3	20.3	33	12	8	9	...	...	2.02	...	4	15	5	10	NW	...	N	L. Townsend.
Bucks	Forks of Neshaminy (Rush Valley).	...	...	...	...	42.8	...	...	...	...	...	...	...	...	...	...	...	...	...	2.04	...	9	14	7	5	N	N	N	J. C. Hilsman.
Bucks.	Quakertown.	536	30.18	30.79	29.30	38.6	66	12	10	30	50.7	27.1	23.6	37	8,9	14	29	87	33.5	2.31	...	10	8	17	5	SW	NW	NW	J. L. Heacock.
Cambria.*	Johnstown.	1,184	30.15	30.76	29.40	40.3	69	8	10	19	49.6	30.3	19.3	44	8	8	29	...	...	2.51	...	15	1	11	18	S,SW	...	S	E. C. Lorentz.
Cameron.	Emporium.	1,030	...	...	...	38.8	66	9	9	19	47.3	29	18.3	37	9	8	27	76.3	32	4.01	2.5	12	7	3	20	W	W	W	T. B. Lloyd.
Centre.	State College.	1,191	30.12	30.76	29.16	37.5	62	11	9	30	45.6	28.4	17.2	40	17	6	3	77	30.4	2.91	2.8	7	2	11	17	W	W	W	Prof. Wm. Frear
Chester.	West Chester.	455	30.17	30.79	29.28	41.1	65	10	12	30	50.6	32.9	17.7	33	17	7	5	70	31.5	2.29	...	11	17	3	10	NW	NW	NW	Jesse C. Green. D. D. S
Chester.	Coatesville.	380	...	...	...	40.3	69	12	11	31	52.4	28.2	24.2	46	9	13	5	...	...	1.78	...	9	14	6	10	W	W	W	W. T. Gordon.
Chester.	Kennett Square.	275	...	...	...	40.1	...	...	...	...	...	...	...	...	...	...	...	...	...	2.29	...	11	13	5	12	NW	...	NW	Benj. P. Kirk.
Chester. *	Phœnixville.	183	30.19	30.82	29.36	44.7	68	12	15	30	52	30.8	21.2	33	8,17	13	24	80.2	29.8	1.69	T	12	10	6	14	NW	...	NW	Knowles Croskey
Chester.	Westtown (29 days).	350	...	...	...	42.2	65	10	14	30	50.9	33.6	17.3	32	17	6	27	...	...	1.41	...	...	...	...	...	...	...	...	T. H. Haines.
Clearfield.	Grampian Hills.	1,450	30.05	30.56	29.21	34.5	60	9, 10	8	19	42.6	28.1	14.5	34	17	4	1.5	...	...	3.35	6	14	3	12	15	W	W	W	Nathan Moore.
Clinton.	Lock Haven.	560	...	...	...	39.4	67	9	10	38	47.7	28.9	18.8	39	9	5	5	...	...	2.72	...	9	13	4	13	W	W	W	Prof. John A. Robb.
Crawford.	Meadville.	1,300	...	...	...	38.8	70	9	9	10	47.5	30.2	17.3	39	17	5	3	...	...	...	...	...	5	10	15	...	...	...	E. C. Williams.
Cumberland	Carlisle.	480	...	...	...	38.4	66	8, 10	13	30	50.7	30.3	20.4	42	8	5	5	84.5	34.5	1.70	2	10	11	9	10	SE	NW	NW	J. E. Pague.
Dauphin.*	Harrisburg.	361	30.19	30.82	29.39	41.1	68	23	14	30	48.9	33.3	15.6	32	17	5	29	69.1	30.3	1.95	...	12	8	13	9	W	...	W	Frank Ridgway. Ob. W'th. Bu.
Delaware.	Swarthmore College.	190	30.16	30.72	29.49	41	67	10	13	30	52.4	32.5	19.9	30	17	12	24,26	77.3	34.9	1.62	...	6	14	6	10	NW	NW	NW	Prof. Susan J. Cunningham.
Erie.*	Erie.	681	30.06	30.60	28.92	40	73	9	18	19	46.2	33.7	12.5	24	23	4	14	73	31	3.99	...	20	2	6	22	S	...	S	Peter Wood. Ob. W'th. Bu.
Fayette.	Uniontown.	1,000	...	...	...	42.5	70	16	17	19	50.9	34.2	16.7	32	9,16	5	5	...	...	3.55	...	10	11	10	9	...	...	...	Wm. Hunt.
Fulton.	McConnellsburg (23 days).	875	...	...	...	41.8	63	9	13	19	51.8	29.3	22.5	38	8	6	5	78.8	35.6	3.03	2	5	10	6	7	W	NW	W	Thomas F. Sloan.
Huntingdon.*	Huntingdon.	650	...	...	...	39.1	66	9	12	19	49.9	28.4	21.5	38	9	7	1	...	...	2.39	3	7	8	11	11	W	...	W	Prof. J. A. Swigart.
Lancaster.*	Lancaster.	413	30.21	30.72	29.06	41.8	64	10	12	30	50.9	32.7	18.2	30	10	10	5	81.6	34.4	1.09	...	5	11	13	6	NW	...	NW	Lewis T. Lampe.
Lawrence.	Newcastle.	932	...	...	...	41	73	9	13	30	48.4	30.2	18.2	35	8	6	22	...	...	3.62	4	7	4	17	19	SE	SE	SE	Wm. T. Bolz.
Lebanon.	Lebanon.	474	30.18	30.80	29.20	39.5	62	23	13	30	50.1	31.1	19	46	22	8	5	76.7	31.1	2.14	0.3	10	7	13	10	NE	SW	SE	Geo. F. Hays. C. E.
Lehigh.	Coopersburg.	520	...	...	...	39.7	64	12	13	30	50.5	31.1	19.4	32	17	6	29	...	...	2.27	...	10	11	8	11	NW	NW	NE	Dr. M. H. Boye.
Luzerne.*	Drifton (25 days).	1,655	30.17	30.53	29.38	34.9	57	23	8	30	44.9	24.9	20	31	9,18	10	24,27	72.6	30.9	4.38	0.2	5	8	12	8	...	...	...	J. R. Wagner.
Luzerne.*	Wilkesbarre.	575	...	...	...	40.4	66	9	18	18,30	50.8	29.6	21.2	39	8	11	29	...	...	2.63	2	9	12	1	17	NW	...	NW	A. W. Betterly.
McKean.	Smethport.	1,500	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	Armstrong & Brownell
Montgomery	Pottstown.	150	...	...	...	42.5	66	10	14	30	52.8	32.6	20.3	33	17	5	23	76.9	34.5	1.58	...	5	17	5	8	W,NW	W	W	Charles Moore. D. D. S.
Philadelphia.	Philadelphia Weather Bureau.	117	30.20	30.84	29.38	44.2	66	10	15	30	51.6	36.9	14.7	27	17	3	29	72	33.5	1.70	...	9	11	9	10	NW	...	NW	Luther M. Dey. Observer
Philadelphia.	Philadelphia (Centennial avenue).	120	30.20	30.84	29.37	44.7	67	10, 12	15	30	53.3	35.7	17.6	23	17	9	11	79	35.8	2.36	...	9	13	10	17	NW	NW	NW	John Comly.
Schuylkill.	Girardville.	1,000	30.13	30.67	29.37	37.2	63	11	12	20	46.5	29.2	17.3	30	17	6	29	...	...	5.12	0.5	9	16	6	8	W	W	W	E. C. Wagner.
Snyder.	Selinsgrove.	445	30.19	30.73	29.43	39.6	56	22	20	29	48.7	27.2	18.5	37	17	5	1	81.8	34.1	3.85	1	8	7	10	13	NW	NW	NW	J. M. Boyer.
Somerset.	Somerset.	2,250	...	...	...	38.2	66	8	7	19	46.5	27.1	19.4	37	7	7	15	85.5	34.1	2.45	0.5	7	8	6	21	SW	SW	SW	W. M. Schrock
Tioga.	Wellsboro.	1,327	30.12	30.74	29.17	34.4	64	9	10	29	43.2	26.1	17.1	30	8	6	1	81.9	68.2	4.21	5.5	12	2	9	19	N	S	S	H. D. Deming.
Union.	Lewisburg.	450	...	...	...	40.6	68	8	15	30	49.1	32.1	17	39	8	4	5,23	...	...	3.45	1	7	11	9	10	SW	SW	SW	F. O. Whitman.
Warren.	Columbus.	1,410	...	...	...	37.4	70	9	10	19	44.2	30.6	13.6	40	7	0	17	62.6	23.5	5.10	3	20	2	8	20	SW	SW	SW	Wm. Loveland
Wayne.	Dyberry.	1,100	...	...	...	34.3	66	8	6	30	46.1	24.3	22.8	46	8	4	1	...	...	1.85	2	8	6	15	11	NW	NW	NW	Theodore Day
Wayne.	Honesdale.	1,000	...	...	...	36.3	60	17	8	30	45.4	27.2	18.2	34	9,17	4	11	...	...	1.82	0.5	8	...	...	...	...	...	...	John Torrey
Westmoreland.	Ligonier.	1,750	...	...	...	41	73	9	7	19	53.8	28.3	25.5	55	19	8	22	...	...	2.93	...	12	9	12	9	...	...	...	J. T. Ambrose.
Wyoming.*	South Eaton.	660	...	...	...	36.2	64	9	13	30	49	29.4	19.6	37	8	5	30	...	...	2.84	1	8	7	4	19	S	...	S	Benj. M. Hall.
York.*	York.	385	30.11	30.72	29.35	39.4	66	10	16	30	52	26.7	25.3	40	8	11	23	84.1	33.6	2.13	1	10	14	5	11	NW	...	NW	Mrs. L. H. Grenewald

*Observations taken at 8 a. m. and 8 p. m.

†Observations taken at noon.

L. M. DEY *Observer in Charge.*

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Philadelphia
Journal

Engineering

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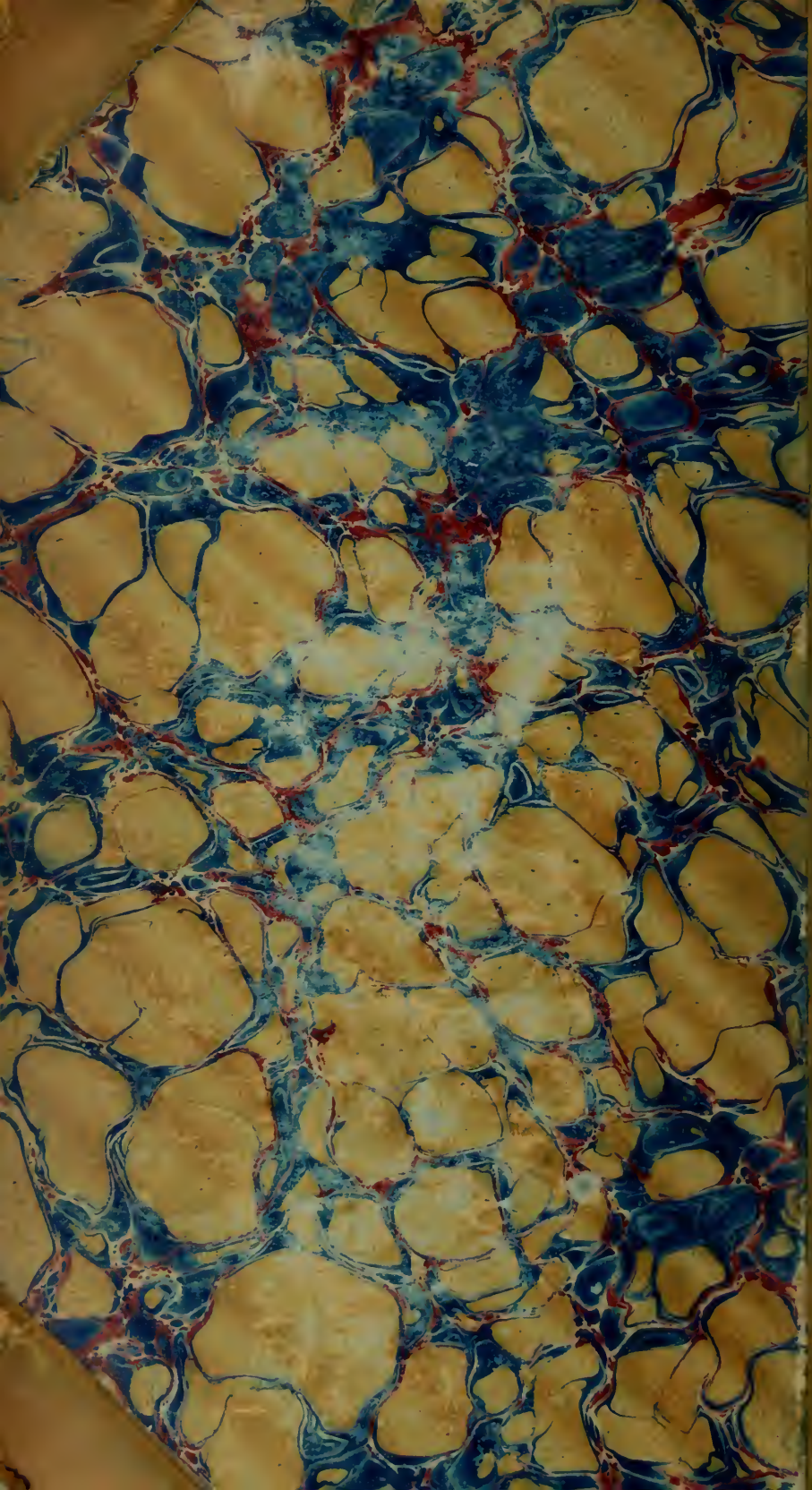
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